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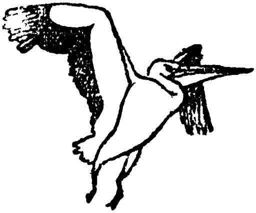

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PREFACE

THE idea of writing this book originated during the last year of the war. It seemed obvious that if Britain's science could be so effectively planned for war, so likewise it could be for peace. Again, it seemed obvious that Britain would need to use all its resources to take its full part in international affairs, to repair the ravages of war, and to put industry on a peace-time footing. For these reasons the Association of Scientific Workers asked a group of its members to prepare a book for the general public on what science could do and how science should be used in peace.

This book does not attempt to portray a scientific Utopia; it is not concerned with wonders of science and the building of dream cities; it does not concern itself with test-tube babies, or pills instead of steak for lunch. It is concerned essentially with the practical problems of the country, in industry, health and the home. Proposals are made for using existing scientific knowledge to increase efficiency, and for planning research in order to obtain new knowledge in fundamental and applied science. The atomic bomb can be said to be the dramatic and horrifying climax of one line of research for war purposes. A like intensity of scientific and technological effort can be expected to yield equally revolutionary advances for constructive social ends. The book refers mainly to Britain in the next five to ten years, although long-term trends are discussed throughout. No attempt is made to draw a complete blue-print for Britain or for British industry. Within the scope of a book of this length it is possible to deal only with a limited number of topics, and where certain industries are mentioned they have been chosen as representative examples, not in every case the most important, of British industry as a whole. Some important industries have had to be omitted entirely or have received only brief consideration.

In writing this book much help has been given by experts in many fields of science in supplying material and criticism. Individual members and groups of members of the Association of Scientific Workers are responsible for most of the material, but assistance was very kindly given by some non-members. In many of the proposals given, no claim can be made for originality. At this time many organisations have produced reports, and several Government White Papers, reports, etc., have included recommendations for the use of science; full use has been made of this published material in our effort to put forward proposals which would meet with acceptance.

Chapter 1 is concerned with world international co-operation as outlined by the representatives of the United Nations, and forms the background against which the rest of the book is written. Chapter 2 discusses some of the problems in British economy in the next few years. Chapters 3 to 6 are concerned with four of the key industries of Britain in which radical improvements and increased scientific research are urgently needed to improve efficiency. Chapter 7 deals with two young industries, Plastics and Fermentations, which occupy only a small fraction of the national economy; they are discussed because both have great possibilities of future development and are closely linked with recent scientific research. In Chapter 7, and in a few instances in Chapters 3 to 6, the introduction of rather more technical matter was unavoidable in developing the argument. These are the only chapters which are likely to present any difficulty to the general reader. Chapters 8 to 10 deal with the social and personal requirements of everyday life: health, food, homes and consumer goods. Chapter 11, on Consumer Research, discusses methods of assessing these requirements and ways in which satisfactory standards of quality and design could be maintained. Chapter 12 deals with problems in administration: how to devise administrative machinery which is both efficient from the scientific point of view, and sufficiently human and flexible to avoid "red tape bureaucracy." Chapters 13 to 15 will probably be of most interest to the scientific reader. In Chapter 13 ways in which fundamental research should be encouraged are discussed, and the subjects most needing investigation are considered. In Chapter 14 proposals are made for establishing appropriate machinery to plan and co-ordinate the scientific effort of the country, and for increased expenditure on scientific research by industry and the State. Chapter 15 is concerned with the problems facing the scientist in keeping abreast of scientific and technical developments and the relevant literature, and in using these. In Chapters 16 and 17 the educational and cultural aspects of science in modern society are considered, followed by Chapter 18 which discusses the education and training needed to produce the necessary numbers of scientific workers. The concluding Chapter 19 deals with the ways in which the proposals made in the rest of the book could be put into practice. It must be emphasised that responsibility for the development and application of science in a democratic country rests ultimately on its citizens. Scientists can only make things possible, but it is the responsibility of every citizen to get things done.

London, September 1946.

INTRODUCTION

THIS book is the spare-time work of a group of mostly young men and women, scientists, engineers and social scientists, who are united in the desire to see the quickest possible application of scientific and technical advances for the benefit of mankind. They, or we, if I may count myself as one of them, are frankly and proudly partisan in our attitude to the main social tasks of to-day. Just as, during the war, few people considered neutrality in the fight against Fascism as either gallant or wise, so we find little to admire in those of our scientific colleagues who, faced by the great social problems of our time, are so frightfully scientific that they are unable to make up their minds on which side they stand.

I think this book is a good book. I know it could have been a better one if we had been able to draw on a wider group of experts to help us. May we hope that one of the results of the book will be that more of our scientific colleagues will be persuaded to stop sitting on the fence and come down to help us write a better book next year?

Another characteristic of the group which wrote this book is that they do not consider economics and social science as inferior kinds of activity hardly worthy of the notice of the natural scientist. This view we rebut most emphatically. On the contrary, we consider that the social sciences in general differ mainly from the natural sciences by being more difficult, both by reason of the complexity of the phenomena and because their subject matter is often charged with an emotional and political content. We believe it to be of great importance that this artificial and stultifying separation of the social and natural sciences should cease. May this book assist them to come together!

The reader will be struck by the very wide range of interrelated subjects treated in one book, and he may wonder why such a comprehensive review has been so seldom done before. He will no doubt reflect that, after all, there has existed no body, either governmental or professional, which could have taken so wide a view. The subjects treated are variously the concern of private industry, or of numerous, largely uncoördinated, government departments. There is no central body yet in existence which could be officially entrusted with the task of making such a survey as has been attempted here. This book will have justified its production if it brings to a wider section of the public a realisation that such a central body is needed, and an understanding of some of the tasks which it should undertake.

P. M. S. BLACKETT
PRESIDENT
Association of Scientific Workers

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I

WHAT SORT OF WORLD?

TO-DAY everyone knows something about the part played by science and scientists in winning the war: in the development of weapons and ways of using them, in industry, medicine, agriculture, nutrition and many other fields. It is also generally realised that during the war Britain achieved new forms of organisation and planned direction of scientific effort which have built up, from limited resources of scientific man-power and facilities, a powerful and effective scientific service. This book is concerned with the future of British science and with the application of its new strength to the solution of the problems of peace.

The Tasks of our Epoch. These problems are of two main types. First there are the pressing problems of reconstruction and the repair of economic and physical war damage. But their solution is only the prelude to the major task of the twentieth century—the fulfilment of the promises of the Atlantic Charter and of many subsequent international declarations, namely, the elimination of hunger and want from the world. In Britain alone the technical problems of social advance are great enough, and include the provision of homes, transport, clothing and other necessaries, the increase of national productivity, the extension of health and social services, the provision of adequate diets for all. But these problems are relatively insignificant compared with the problem of raising the living standard of the human race as a whole, problems such as exist in India and China and other tropical and sub-tropical countries. These are the supreme tasks of our epoch. They call for the mobilisation of the resources of the earth to meet the needs of its peoples on a scale hitherto unknown. These things must be done, not for humanitarian reasons alone, although these would be adequate stimulus and encouragement, but because prosperity, like peace, is indivisible; the prosperity of one country depends on the prosperity of all. The Atlantic Charter is sound economics as well as sound humanity.

What Science Can Offer. The development of science and the use of science are closely connected with all these problems. Science is a socially acquired body of knowledge about the world and universe, and is at the same time a method of consciously extending and of using this knowledge. With the development of science, civilisations have become increasingly dependent upon its use in enlarging their mastery over nature, so as to be able to support large populations at standards of living above the primitive. At the same time science has increased man's power of destruction; it has made wars both more extensive and more terrible. When applied to industrial production in certain social systems science can intensify economic crises of overproduction; it can then appear to be the cause of unemployment and of much human suffering. So the modern world shows a series of sharp contrasts involving science—the contrast between what industry could produce and what people can buy, the contrast between the large-scale use of science for destruction in war and the failure in many countries to use it for constructive ends in peace.

None of these baleful effects of using science is the "fault" of science. Science is neither good nor bad; it is organised knowledge and a method, a tool or weapon, which society can use for good or evil. It can confer the highest benefits and it can be used to destroy.

It is not too much to say that one of the root problems of our times is the problem of the proper use of science. This is fundamentally a social and political problem, whose solution can only be found through the study of societies and in political action. It is not the purpose of the book to prove this, which is already sufficiently clear to thinking men and women. But it is the purpose of this book to examine and to indicate the possibilities of social advance which science and technique offer, and to show some ways by which Britain can more effectively contribute to the common task. One conclusion emerges perhaps more clearly than any other from a survey of the technical potentialities: the state of knowledge to-day is such that *there are no technical obstacles to worldwide social advance.* The reasons for any failure to advance should be sought not in the laboratories and libraries of science but in the structure of society itself and in the means by which it orders its affairs.

Conditions for Achievement. There is only one economic and political context in which the high aim already set forth can be attained—that of an internationally planned and expanding economy, aimed not only at high but at rising standards of life, and supported by all nations working together. Such economic and political co-operation, made possible by the common experiences of the war against Fascism, is symbolised by the United Nations Charter. The United Nations Food and Agriculture Organisation is a step to the practical realisation of this ideal in one important field.

Further, these aims require the rapid development of industry and the use of natural resources in the backward countries themselves. This is especially true of India and China, where no solution of the agrarian problem appears possible without industrialisation. (See Chapter 2.)

Finally, in individual countries, as in Britain, internal policies of full employment, social security and rapid technical progress will be needed if the world plan is to succeed. These are important social objectives in all countries. Britain knows only too well the consequences of restrictive economic policies: depressions, unemployment, misery and dereliction. It is to restrictionism and unemployment that much of the technical backwardness of certain sections of

British industry to-day may be traced. While millions were unemployed and human labour was cheap, little incentive to technical progress could exist.

These, then, are the general conditions within which the broad objectives of world advance can be realised and science can play its full part in the improvement of man's estate. In the succeeding chapters the contribution that Britain could make to this objective, which will affect every member of the population, is considered.

2

SOME ASPECTS OF BRITISH ECONOMY

THE POST-WAR POSITION

In some measure, the general character of British economy has retained its pre-war pattern. That is to say, Britain remains a predominantly industrial nation dependent on overseas trade for the importation of much of its foodstuffs and raw materials. The Labour Government, which was returned in July 1945, has been faced however with certain major changes. In the past, as a creditor nation Britain made extensive use of returns on overseas investments to balance trade and to pay for part of its imports; this phase has largely passed. Britain has also, in some cases in common with other highly industrialised countries, used its dominant position to restrict the growth of industrial developments in other parts of the world, including its colonies and India. This phase, too, must pass.

These prospects have given rise, among certain industrialists, to such alarm and despondency as to produce from the *Economist* (8th June, 1942) the comment: "They forecast a Britain brooding like an ancient miser in the twilight over a dwindling treasure." Apparently all that these pessimists can foresee is a repetition of the attempt to seek salvation by the old devices of secret agreements, financial manipulations, commercial "astuteness" and all the paraphernalia of the policy of restriction.

The real potentialities of international trade have, however, hardly been tapped. Professor Eugene Staley in his book *World Economic Development* (International Labour Office, 1944) gives figures which graphically portray the possibilities. Thus China alone has immediate requirements for 100,000 miles of railway, needing 20,000,000 tons of steel, 25,500 locomotives, 300,000 freight cars, 30,000 passenger cars; 500,000 automobiles a year for ten years; 1,000,000 miles of new roads; power plants to produce 20,000,000 kilowatts; 80,000,000 telephones; 320,000 cotton looms. The position of India is similar. To bring the rest of the world up to United States consumption levels would require 600,000,000 radio sets, 350,000,000 telephones plus corresponding central station equipment, 450,000,000 additional automobiles. As Professor Staley says: "For the attainment of a minimum level of 'freedom from want' and still more for the satisfaction of some of the newer wants that arise where superior living standards are attainable, the level of production throughout the world would have to be raised enormously."

Previous experience does not suggest that such industrialisation of backward countries will lead to a permanent drop in our total of international trade, but rather the reverse. In 1939 exports from Britain to the following countries, per head of their populations, were: New Zealand, £12; Australia, £5 6*s.*; Canada, £2; U.S.A., 3*s.*; India, 1*s.* 9*d.*; China, 2½*d.* It is clear that it is not industrialisation of the importing country which brings about a low import level, but that lack of industrial development results in a low level of purchasing power.

Even without such an expansion of international trade, the position of Britain is not so weak as some try to suggest. In the years 1936–1938 the total average annual exports of Britain were £540,000,000 and the imports £930,000,000. The balance was made up mainly by returns on overseas investments £200,000,000, and payments for shipping and banking services £150,000,000. But the National Income was £4,300,000,000, exports forming 12½ per cent of this. Thus the home market was far more important than those overseas.

As Sir William Beveridge has said, other countries will need to sell their produce to Britain, and hence British long-term contracts for primary products from overseas might "promote stability of demand for our exports"; in the worst possible circumstances (great difficulty in exporting) imports could be decreased very considerably. Britain now produces a greater proportion of its food requirements than before the war; many of the pre-war imports were, comparatively speaking, luxuries that could be dispensed with if necessary. The Ministry of Production said (May, 1944) that "the imports of raw materials for industry in 1943 were down to 40 per cent of the average pre-war year and yet the total industrial production of the U.K. was about 40 per cent higher than it was in 1938."

The key problem both for Britain's home and overseas trade is to expand purchasing power. The biggest factor in Britain's pre-war economic difficulty was the inadequate purchasing power of the greater part of the home population, coupled with the fact that the concentration of a considerable part of the National Income in the hands of those who necessarily spent a great deal of it on luxury products caused a distorted production structure.

To increase purchasing power for the community the National Income must be further increased; it has increased during the period 1938–1945 from £4,604,000,000 to £8,172,000,000, and only a part of this increase is due to price increases. A further increase in the National Income demands increased technical efficiency and the carrying out of a real policy of Full Employment. The better distribution of purchasing power depends on taxation policy which taxes higher incomes more severely than lower ones and upon extended national social services of education, health services and pensions. Taken together, these policies would create a much larger potential home market for an increased level of production.

THE NEED FOR PLANNING

Among the first essentials of an expansionist economic policy is a greatly increased degree of international and national planning. The idea of a planned economy is anathema to many, but by no means all, of the leading industrialists in Britain. The subject is certainly complex but it is one of the key problems of the age. Unless it be solved, schemes for international and national co-operation in pursuit of the four freedoms are doomed to failure. Properly conceived, planning is not an attack on individual liberty, but is rather a defence and extension of it. The problem is really not whether to plan or not to plan, but: Who shall do the planning and for what ends? The larger industries, in their grouped and cartelised forms, already provide a relatively efficient planning mechanism. Their objectives are, however, often completely antagonistic to the well-being of the community as a whole. The economic effects of the policies of these groupings and cartels are usually incompatible with the expansionist economy advocated here.

On the international scale, the formulation of the general pattern of world trade should be the task of the various governments, assisted by advisory groups of industrialists and trade unionists. The aim should not be to plan the trade of any country in detail but rather, in the manner of the Hot Springs Conference for agriculture, to analyse the world position in respect of the peoples' needs, availability of labour and raw materials, etc., to derive from this analysis estimates for the required production and trade and to suggest a broad basis for schemes of financial assistance where necessary. Certain of these estimates, for instance the distributions of raw materials in short supply, may need enforcement.

In Britain it is becoming increasingly necessary for Government control to be exercised over certain basic industries, notably fuel and power, transport and certain of the more important sections of the heavy chemical and raw material industries. This is partly because their importance to the whole industrial system is such that governmental international planning would be nullified by lack of this control, and partly because the inefficiencies and anarchy in these industries can no longer be tolerated.

A word of warning is necessary however on the form of nationalisation which is being adopted by the present Labour Government, based on a study of the first year's legislation in this field. Two major weaknesses emerge. The first is the extremely heavy compensation which is to be paid, which will act as an economic burden on the nationalised industries for many years. The second is the composition of the Boards appointed to run the industries. Up to the present, they are dominated by precisely those interests whose control nationalisation is intended to supersede. The Trade Union and technical representation which could contribute best by virtue of its working knowledge of the productive side of the industry is in a small minority. Valuable contributions to the open planning and organisation of production were made, during the war, by Joint Production Committees; the development of these Committees should be greatly extended. Such organisations as Joint Production Committees could help enormously to eliminate mistrust and to encourage more productive working. The tendency to secrecy in planning is found in government departments as well as in industry. It is desirable that government departments should themselves set an example by encouraging public discussion of their plans as early as possible (except of course where security questions are concerned).

In certain important industries not scheduled for nationalisation, such as Cotton, Pottery, etc., the Labour Government has set up Working Parties: "To examine and inquire into the various schemes and suggestions put forward for improvement of organisation, production and distribution methods and processes in the industry, and to report as to the steps which should be taken in the national interest to strengthen the industry and render it more stable and more capable of meeting competition in the home and foreign markets."

Finally, reference must be made to the argument by the protagonists of private enterprise that industrial competition is necessary as a stimulant to technical progress and that a planned or state-controlled industry will tend to stagnation. There will, of course, always be the need for individual initiative in developing technical efficiency. But in fact, as between firms in many of the major industries, the tendency towards cartelisation has already stifled effective competition. Effective technical rivalry is admittedly stimulating, but in many fields the stage has already been reached where this is more likely to be achieved through planning and co-operation than without it.

LEVELS OF TECHNIQUE AND EFFICIENCY IN INDUSTRY

While certain of the newer industries in Britain are well equipped and technically efficient, the older basic industries are often technically backward and in drastic need of major overhauling and re-equipping. Scientific and technical skill may be considered in relation to a number of aspects of British industry. These aspects may be described as research and development, planning, marketing and servicing, creation of flexibility and efficiency of production. In Britain it has been generally accepted in the past that fundamental scientific research is a task mainly for the universities. The larger industries have, however, already set up organisations to carry out advanced development and long-term research, and are beginning to carry out a greater quantity of fundamental research. The development of fundamental research in industry should continue on an increasing scale, but with certain significant changes in attitude. One of the primary essentials for the effective prosecution of work of this nature is the widest possible interchange of ideas; this means the greatest freedom for publication and discussion of new work. It is also important that research should be pursued by thoroughly competent staffs working in favourable conditions, i.e. in well-equipped laboratories with conditions of academic freedom. This requirement is beyond the scope of the relatively small units in many British industries; its achievement demands the whole-hearted support of existing Research Associations and the creation of new ones. In the past such Associations have been grudgingly financed and supported. This has been attributable in part to the tendency of the constituent units to be unduly jealous of their sovereign rights, and to a failure to understand that the best way to improve the technical level of the industry and of its units is, in the long run, to foster general research of value to all. The grudging is also in part a manifestation of the attitude which condemns scientific methods because half-hearted and inadequately financed experiments, undertaken by inadequately qualified personnel, have not quickly yielded profit-making results. Finally, a major contributory factor causing restrictions in scientific research is that the manufacturing side of many industries tends, by virtue of the magnitude of its capital investment, to be highly conservative.

Technical planning for the use of products, and technical knowledge in marketing and servicing, are of increasing importance: to a large degree effective utilisation of machines, tools and apparatus has not kept pace with technical advances in their production. Some lessons can be learnt from war-time experience, when it has been necessary to develop new methods of ensuring the best utilisation of technical equipment—of assessing the requirements of users; this has been attained by the deliberate establishment of organisations of scientists linking together producers and users, e.g. the "operational research sections" attached to the Services. These developments, however, have shown up the lack of adequately trained operating and maintenance staffs. A policy of development of the more backward countries would make this problem acute and would require a large degree of planned co-operation.

In the past, British industries, with certain exceptions, have made inadequate use of technically qualified and able men as foreign representatives, and for advising, servicing and maintenance. Such representation has been guided too much by the old traditions of sales organisation. In the times ahead it is imperative that industry's representatives should be fully qualified to give first-class technical advice, to help their customers to plan projects, to train them where necessary in handling the industry's products and generally to inspire that confidence which is bred only of mastery of the subject. There is much to be learned from American practice in this subject. The criterion of the market has been regarded as the sure evidence that a product has fitness for function or conforms to a user's needs. In the export market it has often been a complaint that manufacturers have adopted a take-it-or-leave-it attitude, and have then shown surprise when markets have been lost. Techniques of research into consumers' needs now make it possible to examine in advance the purpose for which an article is required and to design it accordingly. In some industries this has always been the case, e.g. in many branches of the engineering industry. Now it can be applied to mass-produced consumer-goods; and the effectiveness of the product in daily use can be measured by scientifically-devised criteria. Moreover the consumers' preferences can be ascertained in advance of large-scale production, so that waste of effort and raw material can be avoided.

The next important task for science in industry is to give assistance in establishing that flexibility and adaptability which will be of paramount importance in the immediate post-war years and probably for a long time to come. The conception that society exists to support industry and that industry's prime function is to provide employment should be inverted. It should be understood that industries which are of prime importance to-day may be redundant tomorrow. There have been many instances during the war where large industries have been adapted in a comparatively short time to make a completely different class of product; when necessary this can be done in peace-time. Of course, changes of this kind are not easily carried through; the technical difficulties alone are great. When these are overcome, as war-time experience has shown they can be overcome, many human problems remain, e.g. problems of the supersession of skills, retraining, the change of working habits and conditions, changes in responsibility and remuneration, and many more. The most sympathetic and careful handling will have to be given to these problems under peace-time conditions. British workers are as adaptable as any, but the reasons for changes should be made plain to them and they should not be expected to forfeit conditions and standards of living for which their trade unions have fought for decades. These problems are, however, much less difficult than the terrible problems of industrial decay and depression; granted real co-operation between Government bodies, industrial management and the workers and their unions, they can be solved.

The possibilities for improvements in the actual technique of production are immense, but in practice are hedged in by a variety of complications. There is an urgent need in most industries for a more enlightened application of scientific methods, as for instance, careful and complete economic studies on the optimum life of machines and plant, and the rational planning of obsolescence and replacement.

STATISTICAL METHODS AND QUALITY CONTROL

Statistical techniques have been increasingly applied in industry during the war. The aim of these methods has been to increase production and to reduce waste. One important field is "quality control" which gives a continuous check on machine performance, and indicates tendencies to produce waste before the waste occurs. Its application is being extended from the engineering industries where it originated, to the chemical industry, to metallurgy, and other important spheres. It offers new criteria on the practicability of specified tolerances, and gives the process-planner a clear indication of the limits to which his machines can be expected to work; the operatives' errors are separated from machine errors. During the war the Ministry of Supply set up an Advisory Service of Quality Control and the excellent handbooks produced by the Ministry of Labour have done much to assist industry to adopt these methods.

Statistical methods can be widely used in industrial planning. A field in which some progress has been made is the statistical analysis of marginal costs; this will make possible more accurate costing and control.

PSYCHOLOGICAL SELECTION OF PERSONNEL

Since about 1942 all three Services have used psychological methods in selecting personnel. The results justified the hopes that were entertained; nearly 100 per cent success was achieved. The method has its application in industry, and was to some extent used before the war. Every type of work can be broken down by a scientific "job analysis" of every function to be performed. On the basis of this analysis, tests are selected or devised to pick out the people with the qualities essential for the needs of the work. This technique can be applied at all levels; in the Army it has been used for such diverse ends as picking leaders of paratroops or prospective tank-mechanics.

PROBLEMS OF SKILLED AND UNSKILLED LABOUR

With the changes and developments in industry envisaged in this book, conflicts between managements and the workers' organisations may arise unless special attention be paid to avoiding them. The workers and their unions are often accused of having no interest in industry except in the size of the wage-packet and conditions of work. This criticism is easily made by those whose own salaries and living conditions are so good that they do not have to worry about them. It must always be remembered that the trade unions have grown up during long years of unimaginative and often brutal handling by employers, when workers have been looked on as "hands" and their labour as just another commodity to be bought as cheaply as possible. The unions' apparent concentration on the fight for material standards has been a matter of sheer necessity. The unions will not be any less active than managements in helping industrial reconstruction and in organisation when they are convinced that reconstruction does not mean worse material and social conditions for the workers. Thus the granting of the Miners' Charter and the fullest co-operation of the National Union of Mineworkers would appear to be of decisive importance in the success of the nationalised Coal Industry.

It has long been a point of attack on the industrial system that it has replaced the craftsman by the unskilled worker —the machine-minder. It is to be accepted that the latter class of work is, in general, intellectually frustrating and that such workers can find little relationship between their work and the satisfaction of human needs. The logical successor to the craftsman of old is the technician of to-day. This is not to argue that an enlightened society would not do everything to retain and encourage the older crafts in appropriate spheres. But in those industries where large-scale production methods are inevitable in order to achieve high standards of living throughout the community, it is the technician's work which is intrinsically satisfying. In many of these industries the machine-minder is an anachronism who should be replaced by the use of more automatic methods, and by workers having a greater variety of responsibility and technical interest. Two difficulties stand in the way: the fear of unemployment, with resultant opposition of the unions, and the present inadequate technical standards of the available labour. A planned expansionist economy would eliminate unemployment; increased technical education would solve the other problem.

PATENTS, THEIR USE AND ABUSE

Whatever views may be held about the justification of deliberately granted monopoly rights, the present situation in regard to patents is something of an anachronism. The growth of Britain's industrial structure, with its rings and cartels, and the increasing complexity of technical processes, have changed the circumstances to such an extent that the original intentions of the "Patents" Act bear little relation to present-day requirements and practices. The underlying idea of the Act was that monopoly is in principle bad, and that where special circumstances render it desirable, it must be defined, limited, and kept under surveillance. The present tendency to establish tremendously powerful monopoly groups based on the mass effect of a large number of patents and the possession of sufficient financial backing to implement the threat of legal action for infringement, even in the face of dubious validity, was not envisaged and far exceeds the original intentions. The unethical and objectionable practices with regard to patent rights which are the real issue, are only partly the result of the existence of patents in their present form. It is possible that if some of the hoped-for democratisation of industrial control were achieved, the menace would be diminished. The matter is important and urgent. Abuses already brought to light have been a significant factor in the restriction of world trade and in the breeding of international discord.

3

KEY INDUSTRIES OF BRITAIN

I: FUEL AND POWER

INTRODUCTION

FOR any country, particularly for one so predominantly industrial as Britain, *fuel* and *power* are the bases of prosperity. The horse-power available per head of population is an index of technical development and of the standard of living of the people; it is, therefore, imperative that the extraction of fuel and the generation of power shall be as efficient as possible. A cheap and efficient supply of power is one of the essentials for the ordinary citizen, for industry and, increasingly, for agriculture. It must be of great concern to all in Britain that the coal-mining industry is in so serious a condition, for coal, used either directly, or for the generation of electricity or gas, is the main source of power in this country. Electricity can be generated also by harnessing water-power (either as waterfalls or as tidal movement); here there is scope for considerable expansion. But coal will continue to be the main source of electric power until this use of coal is superseded by the use of atomic energy; even then coal will still be increasingly important as a source of chemicals. The fuel and power situation must be considered from all these various aspects. A comprehensive view is essential since the various sources and methods of usage interlock.

THE COAL INDUSTRY

The Present Situation. For many years there has been a growing consciousness of the very serious situation developing in the coal industry, both as to the position of the workers and to the industry's efficiency and modernisation. The simple evidence of impending catastrophe has been the fact that no one has wanted to work in the mines: during the war labour was found only by directing men to work there as an alternative to service in the Armed Forces. So few opted for the mines that compulsory measures had to be adopted; "Bevin Boys" were directed to the mines. Mr. W. Lawther, President of the National Union of Mineworkers, wrote: "How can you run an industry efficiently if every miner loathes his industry because of its owners, if every miner's wife swears 'her boy will not go down the pit'?"

The degree of inefficiency in the industry has also become a source of anxiety to the country. The coal industry grew up haphazard. The richest and most easily tapped seams were exploited to squeeze out large profits quickly; to-day poorer and less accessible seams are our heritage. There has been a multiplicity of collieries using technically antiquated methods. Many collieries have had financial ties with other coal-using industries to which coal is supplied at prices below the average market price. This has had the effect of reducing the apparent profit of the collieries which, therefore, are unable or unwilling to finance re-capitalisation, and their "ascertainments" or statements of profits for determining wages have thus been artificially reduced. The great number of firms has prevented any planning for a coal-field as a unit and "has driven firms in the past to seek quick profits at the expense of ultimate efficiency. There has been failure to mechanise the pits and a neglect of scientific research and development in both production and use of coal. Technical backwardness, primitive standards of labour management, an out-of-date wage structure, and the relative neglect of safety promotion, preventive medical work and welfare services—these are the consequences of comparative inefficiency and the causes of suspicion and ill-will" (*The Times*, October 11th, 1944).

With this state of affairs, not even the coal-owners have been able to put forward convincing arguments for continuing private ownership, and the whole country has welcomed the nationalisation of the industry by the Labour Government through the Coal Bill, 1946. This Bill provides the framework within which it will now be possible to bring about a complete change both in the efficiency of the industry and in the position and outlook of the miners. But the industry is being taken over at such a low level that much solid work and time will be required to achieve this result. Within the Ministry of Fuel and Power and under the Coal Board it will be essential to build up a strong scientific and technical service competent both to deal with the manifold technical, health and safety problems of the industry and also to study scientifically the administrative and distributive problems which will have to be faced. It will be necessary to apply scientific methods with the same energy and purposefulness as was devoted to weapon development and operational research during the war.

The Way to Modernisation. The modernisation of the coal industry must come through increased mechanisation. The highly mechanised coal-mines of America produce three tons per man-shift as against one ton produced in Britain. It has been argued that the collier is opposed to mechanisation on the ground that it will create unemployment. Whether this be true or not, it is clear that the way to overcome such resistance to mechanisation is to restore the confidence of the miners by nationalisation.

The problem of mechanisation of the British coal-mines is essentially different from that of the coal-fields of the U.S.A. or the Soviet Union, where rich thick seams are still being worked. In Britain the best seams have been worked out; thin seams and relatively inferior coals are now the main reserves. It is far more difficult to introduce complete mechanised methods of winning and handling the coal in seams only two and three feet thick, as compared with the four or five feet seams worked in the U.S.A. It is, however, entirely wrong to suggest that this is an insuperable obstacle to complete mechanisation, for this involves not only cutting but also transportation, cleaning and sorting. The problem is to design and perfect plant which is suited for the British coal measures. This implies scientific research and engineering development on a scale which the British coal industry has never in the past shown any readiness to undertake. Mechanisation will require new lay-outs of the underground workings and the sinking of new shafts, in order to get the best results. It should not be left to foreign advisers to suggest methods of increasing the output of coal, while leaving the vital research unattempted. The Coal Board should without delay take over collieries in typical coal-fields, and operate them solely for purposes of research and engineering development. The operations should be conducted on a scale sufficiently large to ensure that the results would be secured within two or three years. There is no time to wait for long-term investigations.

Underground Gasification. There is, at the present day, much interest in the process of underground gasification; this was originally suggested by Siemens and again by Mendeleev (1888); later, Sir William Ramsay drew up a practical scheme and actually sunk a shaft in the Durham coal-field. However, no practical support was forthcoming either from industry or the Government. But Lenin, in 1913, grasped the potential significance of the method. Since the Revolution, the Soviet Union has devoted much research and development to the exploitation of the method. Whilst information on this subject has been lacking during the war, there is no doubt that the Soviet Union by 1938 had made considerable advances in applying this technique on an industrial scale. In the Soviet Union underground gasification, carried out by burning the coal in a stream of oxygen or air, with or without steam and under conditions which lead to the formation of carbon monoxide, is part of a general plan which involves the concentration of industries closely related to coal. The gas obtained can be utilised for (*a*) domestic heating and cooking; (*b*) electrical generation using gas-turbines; (*c*) the synthetic production of chemicals, fuels and lubricants by the Fischer-Tropsch and similar processes. One of the great advantages of underground gasification is that the arduous and dangerous labour of the coal-miner is to a great extent eliminated. Underground gasification, however, cannot be regarded as the cure for all the fuel problems in this country. Even in the Soviet Union it has only been used to supplement the mining of coal by normal processes, and so far, has only been applied to those regions which possess thin, steeply inclined seams and coals of high ash content. Its application to British coal-fields may be extremely limited at the present time. British reserves of good coals are steadily diminishing; nevertheless the setting aside of a colliery for the purpose of research on underground gasification, as was in fact intended in 1914, would give extremely valuable information on possible future developments of the process. The survey of coal reserves being carried out by the Fuel Survey and Geological Survey should provide the basis for deciding the best way to mine the seams, what methods to use to sink shafts and where underground gasification might be suitable.

It has been suggested that the British makers of coal-mining machinery are opposed to new developments which would render their existing plant obsolete. If this be true, it may be necessary for the State to take control, not only of the collieries, but also of the manufacture of coal-mining and coal-handling plant. British engineers were pioneers in mechanised coal-getting forty and fifty years ago, but they have not since made as much progress as foreign engineers in this industry. In the proposals made below for the establishment of research institutes for the fuel and power industries, the first place is given to centralised research into coal production methods.

Health and Hazards. Safety in mines, miners' health and the general conditions of life for mine workers both at work and at home, are all vital factors to be considered if the coal industry is to attract men to maintain output and to use the new machinery. Apart from obvious causes of accidents, such as fire-damp explosions and subsidence in the pits, the miner is subject to lung diseases caused by inhaling dust, and to a host of general accident risks.

The following tables give some idea of the high mortality rate in mines and the incidence of disease.

TABLE 1

*Number of Miners Killed and Injured by Accidents**

		1938	1944
Number of workers killed:			
	Underground	782	573
	Surface	76	50
	All workers	858	623
		1938	1943
Number injured and disabled for over 3 days:			
	Underground	120,366	157,177
	Surface	11,410	16,539
	All workers	131,776	173,716
Number killed and injured per 1,000 employed:			
	Underground	194	287
	Surface	64	92
	All workers	258	379
Total number of persons employed		782,000	710,000

TABLE 2

*Changes in Fatal Accident Rates**

	No. killed per 100,000 *employed*
1920	89.0
1925	102.3
1930	107.1
1935	111.9
1938	107.0

* Statistical Digest, Ministry of Fuel and Power, 1945.

TABLE 3

*Changes in Non-Fatal Accident Rates**

	No. injured and disabled per 1,000 *employed*
1920†	93.3†
1925	158.5
1930	175.1
1935	170.4
1938	163.3

TABLE 4

*Industrial Disease***

Number of cases for which Workmen's Compensation was paid, 1938

	New cases during year	*Total number of cases*
Nystagmus	1,019	5,202
"Beat Hand"‡	999	1,089
"Beat knee"‡	4,505	4,846
"Beat elbow"‡	723	777
Inflammation of synovial lining of wrist joint	345	363
Ankylostomiasis	—	—
Other diseases	175	259

More research is needed on the prevention of diseases of the lungs caused by the inhalation of dust (pneumokoniosis). This class of disease is particularly rife in the South Wales coal-field, where a thousand cases were recorded in 1943. Some research work is being done by the Medical Research Council; the Mines Inspectorate, the Amalgamated Anthracite Collieries Ltd., and the Mining Department of the University of Wales are investigating the effects of water-infusion of the coal-face and spraying in association with machine-cutting, with a view to the suppression of dust at its source. A sufficiently large team of experts, with the finances necessary, should be able to clear up this problem in a reasonable time.

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* Statistical Digest, Ministry of Fuel and Power, 1945.

† After 1924, accidents causing disablement over 3 days were compulsorily reported: previously only over 7 days.

** Secretary of State for Mines Annual Report, 1938.

‡ These are the popular terms for various forms of acute cellulitis and bursitis.

In preventing disease, much more attention needs to be given to the whole problem of ventilation in coal-mines. This is made more urgent by increasing mechanisation, with its tendency to greater production of dust, although, on the other hand, wholesale mechanisation should ultimately give benefit, by reducing human contact with dust—e.g. by cutting down shot-firing (which is a potent factor in dust production in the present non-mechanised anthracite mining).

Treatment of established cases of silicosis (pneumokoniosis caused by silica) with powdered aluminium has given encouraging results in Canadian metalliferous mines; alleviation of symptoms, though not cure, has been reported. A trial of this method in coal-mines in this country is now called for.

Allied to treatment, there is urgent need to put on a rational and scientific basis the early detection of persons with pneumokoniosis, their rehabilitation and, where necessary, re-settlement in suitable alternative work, either within the rapidly expanding coal-utilisation industries or elsewhere. In connection with early diagnosis, mass-radiography requires to be used for the periodic examination of all miners exposed to this dust hazard.

Recruitment to the Coal-Mining Industry. A committee under Sir John Forster* recently inquired into the problem of recruitment for the coal industry. It is clear that far more than has been attempted by the Miners' Welfare Fund will have to be done if the industry is to be made an attractive employment. Emphasis is usually laid upon the inadequate earnings of miners, but much more is involved. Colliery villages are isolated and drab; life is dull for the wives and daughters of miners; attractive employment for the unmarried women is not available; schools are often less well organised than in the big industrial centres. The mine-worker himself, outstanding for his independence of mind and action, chafes at the conditions of living which do nothing to compensate for the unattractive conditions in which he must work.

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* Government Committee on the Recruitment of Juveniles in the Coal Mining Industry.

If the British coal industry is to survive—and without it, all British industry must collapse—there will have to be, within a decade, a complete revolution in the methods of coal-mining. The mine-worker will no longer have to be a man only of courage, brawn and craft-skill, but must become a skilled mechanic and engineer, handling intricate machinery and producing a large output of coal for a good wage. Miners have never received pay commensurate with the risks they have to take, and in the future, even if all possible safety measures are introduced, the miner's calling will remain more dangerous than almost any other. Furthermore, the miner's skill now is great; increased mechanisation will demand additional skills. The mine-workers should receive a wage that will keep them in the first ranks of all industries, and this should be economically possible if the mines are efficiently worked.

Coal is, potentially, the basis of many new industries and these should be built up around the coal-fields. This development would increase the opportunities of employment for the miners' families, make possible better social amenities, and tend to reduce the impact of unemployment in a one-industry area by introducing diversity of employment.

The Distribution of Coal. This is very nearly as unsatisfactory as its production. There are said to be more than 25,000 so-called "coal merchants" in Britain; most of these have no technical knowledge of the coal they sell and they are quite unable to advise consumers or to give them the service to which they are entitled. The costs of distribution are wastefully high. It is no uncommon thing in a small town for four or five merchants to stock a few tons each of a particular kind of coal, with the result that the handling charges may be as high as 12*s.* to 15*s.* per ton; with proper organisation all the requirements of the locality could be handled from a single depot at a third or a quarter of the present cost.

The technical methods of distribution in Britain are primitive as compared with the U.S.A. where in many cities domestic solid-fuels are delivered in packages, with the resulting avoidance of breakage and dirt. There is need now for a complete overhaul of the structure of the coal distributive trade, and of its technical methods, based upon a scientific study of how to achieve maximum efficiency. This will be a very important factor in keeping down the cost of coal to the consumer.

Coal Utilisation. Coals cannot be considered simply as sources of energy for providing heat or generating electric power. Coals are substances of extreme chemical complexity. By suitable treatment they will yield many chemical compounds that are in great industrial demand and which can only be prepared synthetically from other raw materials at greater expense.

The utilisation of coal and the various supplementary natural resources of power has to be considered from this dual standpoint: the main alternative resources are hydro-electricity (including tidal power), petroleum (mainly imported) and fermentation products obtained from agricultural products and sewage (see pp. 55, 99–102). These natural resources are to a great extent interchangeable in the wide variety of requirements which they fulfil. A rough sketch of the main paths through which they pass (or could reasonably pass) is given in Fig. 1. This diagram does not pretend to be exhaustive or to give any idea of the quantitative relations in the present or future flow of the commodities mentioned.

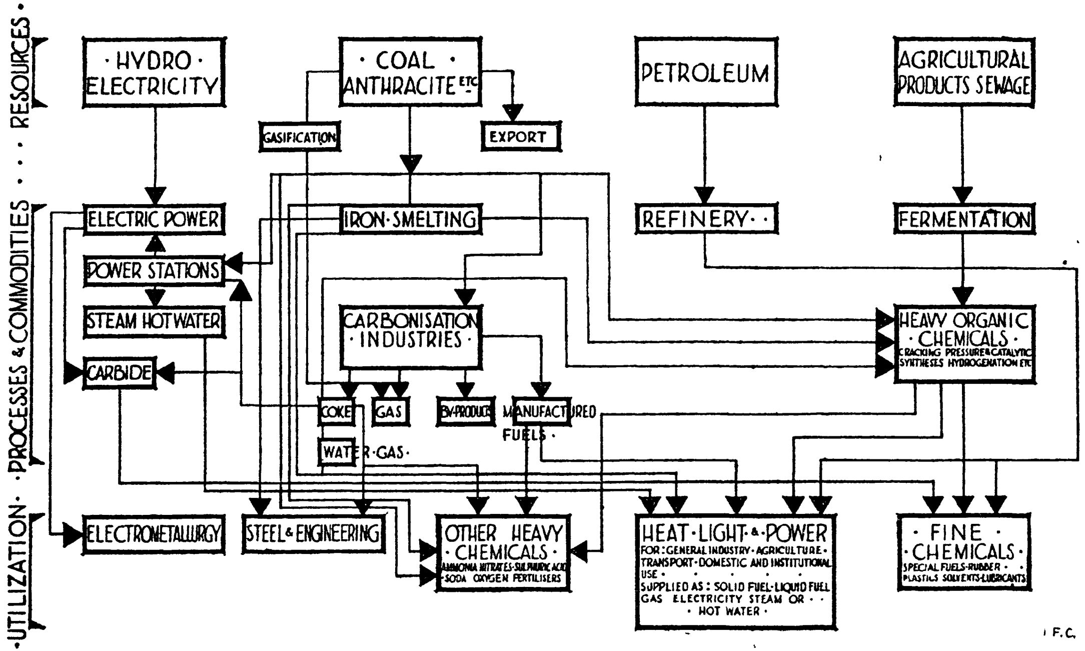
·RESOURCES·
·PROCESSES & COMMODITIES·
·UTILIZATION·
·HYDRO· ELECTRICITY
·COAL· ANTHRACITE ETC.
PETROLEUM
AGRICULTURAL PRODUCTS SEWAGE
GASIFICATION
EXPORT
ELECTRIC POWER
IRON·SMELTING
REFINERY··
FERMENTATION
POWER STATIONS
STEAM HOT WATER
CARBIDE
CARBONISATION ·INDUSTRIES·
HEAVY ORGANIC ·CHEMICALS· CRACKING PRESSURE & CATALYTIC SYNTHESES HYDROGENATION ETC
COKE
GAS
BY-PRODUCTS
MANUFACTURED FUELS·
WATER·GAS·
ELECTROMETALLURGY
STEEL & ENGINEERING
OTHER HEAVY ·CHEMICALS· AMMONIA NITRATES·SULPHURIC ACID SODA OXYGEN FERTILISERS
HEAT·LIGHT·&·POWER FOR: GENERAL INDUSTRY·AGRICULTURE· TRANSPORT·DOMESTIC AND INSTITUTIONAL USE· SUPPLIED AS: SOLID FUEL·LIQUID FUEL GAS ELECTRICITY STEAM OR ··HOT WATER·
·FINE· ·CHEMICALS· SPECIAL FUELS·RUBBER· PLASTICS SOLVENTS·LUBRICANTS
F.C.

FIG. 1. THE IMPORTANCE OF FUEL AND POWER.

Fig. 1 makes clear to what extent this whole group of industrial processes is interlinked. An integrated national policy for the future development of this group of industries *must* be worked out and put into effect. In the past, unregulated competition between the different industries in this group (e.g. in the sale of gas, electricity or raw coal for domestic purposes) and failure to co-ordinate the different branches of industry (many of which are highly efficient as self-contained units) have led to a very great wastage of these resources which cannot be tolerated in the future. The problems to be solved are of great complexity. Factors which will have to be taken into account include: the international trade position in respect of petroleum; the desirability of cutting down atmospheric pollution; obsolescence and new trends in technological (machinery and methods) developments; the types and quantities of coal available; transport considerations; and the demands of localised regions in relation to all of these factors. Furthermore, the by-products of this group of industries, e.g. ammonia and sulphuric acid, are themselves fundamental raw materials for a large number of other industries.

Coal utilisation, like coal-mining, is at present highly inefficient and in need of drastic revision. The tendency should be towards greater utilisation as a source of chemicals. This will mean a decrease in the burning of raw coal for domestic heating, as well as for industrial power and heating. There must also be a thorough re-examination of the generation of electricity from coal and other sources.

To attempt to frame a detailed policy for all these aspects is not possible here; what is urgently required is for the establishment of a single authority, with the necessary executive powers, to ensure co-ordination of the group of industries and to direct into the proper channels the very heavy capital expenditure required to change, in a beneficial way, the present structures and technical methods. This capital expenditure, like that envisaged for coal-mining, will call for great engineering developments—civil, structural and mechanical—and for a great deal of scientific research.

THE ELECTRICAL SUPPLY INDUSTRY

The electrical supply industry is probably the most highly organised section of the fuel and power industries. Through the Electricity Commissioners the development of the industry takes place under State supervision. The whole policy, however, is too isolationist and does not allow of sufficient co-ordination of electric generation, industrial heating and chemical utilisation. The cost of electricity to the consumer is maintained at an uneconomic level, in part by the multiplicity of small and relatively inefficient generating and distributing units, and there is still too great a diversity of tariffs.

Changes in Present Production Methods. The generation of electricity using coal burning in the conventional plant results in a thermodynamic efficiency of 30 per cent for the best modern plant or an average of 22 per cent for the whole country. This means that 70 per cent of the heat produced is lost to the atmosphere or is used in warming condenser cooling water; this lost heat thus serves merely to raise slightly the atmospheric temperature or that of some neighbouring river. Much of this wastage could be offset by using this low temperature heat for some purpose such as domestic heating (district-heating of blocks of dwellings demands very serious consideration) or by using waste steam in an industrial process such as the manufacture of paper. Some of these methods might necessitate a slight increase in the lower temperature of the generating station working-cycle with a consequent drop in its efficiency as a heat engine, but this might easily be more than offset by the large-scale recovery of otherwise totally wasted heat; much higher overall thermal efficiency might then be attained. This, however, is only one of the problems which should be investigated. Recent developments in the gas turbine, for instance, may open the way to large-scale co-ordination of electricity generation with the chemical utilisation of coal.

The position of hydro-electric power also needs careful consideration. In his Hinchley Memorial lecture to the Institute of Chemical Engineers (1944) Sir A. Gibb reviewed the question of hydro-electric power in Britain, with special reference to Scotland. Recent investigations have shown that previous estimates of inland water resources in Britain, including the Severn tidal scheme, were too low and that the potential power from such sources amounts to some 25 per cent of all power now generated. It is true that the capital cost of hydro-electric plant is much higher than an equivalent power station. But this is to a great extent offset by the annual cost of fuel for the latter and by its shorter life. If the full resources of Scottish water-power were developed, this could lead to the rehabilitation of the Highlands and the development of subsidiary industries around the hydro-electric stations. It is estimated that power would be available to industry at a very low cost.* At present the average charge for power distributed by public authorities is 0.64*d.* per unit for industrial power and 1.69*d.* per unit for lighting and domestic use; the comparable figures for electricity supplied by private companies are, respectively, 0.72*d.* and 2.08*d.* per unit. An incidental advantage of hydro-electric power in relation to a national grid is the ease and rapidity with which a hydro-electric station can increase its output to meet sudden unexpected demands. Even where adequate warning can be given, the handling of high peaks of short duration by coal-burning plant is relatively inefficient.

A properly planned British industry could develop on lines which have already been fully established as technically sound in the Soviet Union, namely to regard the whole industry of a given region as a single unit. Electrical generation should not be regarded as a separate activity, but should, wherever possible, be combined with the utilisation of waste steam. Approximately 50,000,000 tons of coal a year are used in Britain for steam-generation in stationary industrial plants (i.e. apart from railways and ships). A further 20,000,000 tons are used to generate steam for electric power production. It can readily be shown that the whole of the steam and power requirements of Britain could be supplied from the 50,000,000 tons of coal if the use of steam and of electric power were combined to the maximum extent. This would involve a drastic reorganisation of the electrical industry; here again, the question of public or private ownership is bound to be a decisive factor. The saving to the country of the equivalent of 20,000,000 tons of coal, at probable post-war prices worth at least £25,000,000 sterling, cannot lightly be set aside.

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* An interesting analysis of the possible contribution of the Scottish Hydro-electric Scheme to the rehabilitation of the Highlands has been made by the Scottish Area Committee of the Association of Scientific Workers: *Highland Power* (Maclellan, Glasgow, 1945).

Although the modern electric power station is a triumph of heavy engineering, the low efficiency already mentioned and the very high capital costs are unsatisfactory features. The anticipated expenditure of some £90,000,000 on new generating plant by the end of 1948 (*Financial News*, November 23rd, 1944), raises even more urgently questions of the design of plant. This is particularly important in regard to the steam-raising plant, in which design is lagging behind requirements. For example, a very high proportion of stand-by capacity (25 per cent or more) is required nowadays to cover stoppages for boiler-cleaning; this affects efficiency, cost and overall capacity. Research on this, and on the fundamentals of boiler design, is on a very small scale in Britain, and is subject to the pressure of vested interests. What is required is a full-scale experimental generating station, under the control of the Department of Scientific and Industrial Research.

New Sources of Energy. The generation of electricity from steam in turbines involves unavoidable losses of energy which place a strict limit on the possible improvements to be expected in the future. It is, therefore, necessary to envisage completely different methods of power generation if really cheap power is to be available in Britain.

It is now probable that the use of atomic energy, by radio-active disintegration of an isotope of uranium (U235) used explosively in the atomic bombs, can be controlled and harnessed for the production of power for industrial purposes, within a few decades. It is also possible that the energy from coal could be converted directly into electricity (e.g. the coal cell); it is believed that active research on these lines has been in progress on the Continent. The standard methods for generating electricity would be completely superseded by the use of atomic energy, or if a great discovery were made, in the direct conversion of chemical energy into electricity. The growing importance of electricity in modern industry makes it essential that research conceived on the boldest lines should be undertaken. The planning and implementation of such research cannot be left to the electrical industry or to the suppliers of the present types of electrical generating plant; it is far too important and revolutionary. This is fundamental scientific research which ought to be supported by the State, and the research workers should be given a free hand to explore possibilities which might not materialise for the next five, ten or even twenty years.

The Utilisation of Electricity. The utilisation of electricity is better developed than is its generation. At least five times more money has been spent on research by the electrical equipment and radio industries than by all branches of the electrical generation industry. Nevertheless, cheaper electricity would be available if the load factor of the electrical industry could be improved, i.e. if power stations could be operated at their full capacity, instead of, as in the years prior to the war, at only one-third capacity. New uses for electricity must be found, particularly those capable of providing "off-peak" loads, and this should be one of the main functions of electrical utilisation research. It seems unlikely that State assistance is needed in this field, in view of the strong commercial interests which are actively engaged.

THE GAS INDUSTRY

Organisation. The gas industry of Britain is in a very unsatisfactory condition. Its organisation has been studied by a Committee of Enquiry* which recommended compulsory purchase of all existing gas undertakings, and the division of the country into ten Regions. In some districts gas-works are operated as municipal undertakings; in others by private enterprise. A few of the larger companies are efficiently run, though some even of the large London companies leave much to be desired as regards both the production and distribution of gas and the service given to consumers. It is the many hundreds of small gas companies throughout Britain, however, which are mainly responsible for the unsatisfactory general level of efficiency. These companies are too small to employ competent administrative or technical staff, and they rely upon the monopolies granted by Act of Parliament to maintain their business. The whole structure of the gas industry requires an early overhaul, probably in the direction of regional co-ordination endorsed by Act of Parliament. This would make it possible to adopt throughout Britain a system of gas-grids, analogous to that which, for example, has proved successful in the Sheffield area. Gas-grids can be operated satisfactorily only if the gas undertakings in a region are under unified control.

Links with Other Industries. The gas industry is important from several aspects besides that of producing gas for heating, etc.; it is closely connected with, and is affected by, certain other industries. An important function of the present gas industry is the recovery and separation of the valuable chemical by-products distilled from coal when gas is made (see pp. 53–4). Research on the methods of treating coal to obtain the chemical raw materials is still in its infancy; but it is probable that, in the future, methods for the direct chemical utilisation of coal, some of which are already known, will be developed, which would give easier and more efficient routes to the desired products. This would decrease the importance of the gas industry as a source of raw materials for other branches of industry. A further important factor in planning the future of the gas industry is the availability of these materials from petroleum, depending on the extent to which refining were carried out in Britain.

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* The Gas Industry. Report of the Committee of Enquiry, H.M.S.O. Cmd. 6699, December, 1945.

Closely allied with the gas industry is the production of coke. About equal quantities of coal are carbonised in coke-ovens and in gas-works, the total for the whole country being about forty million tons a year. Coke which is used in blast furnaces in the manufacture of iron must be of special quality, and is made from coals available mainly in Durham, Yorkshire and South Wales. The finest coke-making coals in the world exist in Britain, but the quantity is very limited, and no attempt is being made to conserve them for the future. Before long, it will be necessary to produce cokes for iron manufacture from coals which have hitherto been regarded as unsuitable for coking. This presents another research problem.

It can be seen that the determination of the future policy concerning coal-carbonisation is not an isolated problem, but can be settled only in terms of a nationally co-ordinated policy designed to secure over-all economic efficiency in the various fields of coal utilisation. Since gas production and coal carbonisation are directly connected, it follows that research, too, should be effectively co-ordinated.

In this way, the sometimes conflicting interests of gas and coke manufacture could be harmonised and the State be provided with information on the basis of which the use of coal could be regulated, so as to prevent the serious shortage of special qualities of coal which threatens to occur within a generation.

SCIENCE AND THE FUEL AND POWER INDUSTRIES

From the foregoing it is evident that technical advances are needed at every stage in the production and utilisation of coal. It will be essential to establish a Scientific and Technical Service for the whole of the Fuel and Power Industries, organised so as to provide the services required by the Ministry of Fuel and Power, the National Coal Board (and similar authorities which may be established later), and the present Research and Development Units and any such future agencies.*

There are at present several separate and largely independent groups of agencies concerned in promoting technical progress in the Fuel and Power Industries. These agencies include the technical sections of the Ministry itself, Government research establishments, University research departments, research organisations financed jointly by the Government and industry, organisations supported wholly by the various fuel industries, including appliance manufacturers and some large fuel consumers. The co-ordination, stimulation and regulation of all these activities should be regarded as a responsibility of the Scientific and Technical Service of the Ministry of Fuel and Power.

The Ministry itself should retain responsibility for certain aspects of coal production, particularly mine-workers' nutrition, health and safety, since they involve

* These remarks are a summary of a memorandum, "A Scientific and Technical Service for the Fuel and Power Industries," printed in *Science and Government*. (Published by the A.Sc.W., 1946.)

legislation and government direction, and also for problems of fuel and power utilisation. To deal with these, the Ministry will need its own highly qualified scientific section as well as Research Units. The National Coal Board and later Authorities in other fuel industries must be responsible for research into production problems, and will, therefore, also need scientific and technical staffs and research units.

All the existing Fuel Research Units and the Coal Survey should come under the direct control of the Ministry, which will need immediate access at all levels to scientific advice, and full control of priorities in the fuel and power research and development programme. These Units should not undergo amalgamation but their activities should be integrated through the Scientific and Technical Service of the Ministry with the assistance of a Research Advisory Council composed of outstanding men and women drawn from science and industry, and including representatives of the Department of Scientific and Industrial Research (D.S.I.R.). The Geological Survey should retain its independent status and be suitably expanded.

In the Ministry there should be a Controller of Research and Development with the rank of Deputy Secretary, and having direct access through the Under-Secretary to the Minister; he would be consulted at every stage of policy formation. Four Deputy Controllers, for Coal Production, Health and Safety, Coal Utilisation, Personnel and Technical Administration should be appointed forthwith, followed by Gas and Electricity when these industries are nationalised. The Deputy Controller for Personnel and Technical Administration would also be responsible for maintaining contact with university departments.

If the coal industry is to be brought to the state of highest efficiency, the research responsibility of the National Coal Board should not be confined to technical matters, but should include all aspects of health and welfare, and teams of social scientists, including medical research workers, should work with natural scientists on problems such as pneumokoniosis.

The research programme required by the Ministry should be carried out in self-contained Research Units under its control, rather than directly by the Ministry itself. Such units should remain autonomous, their general policy and their programmes being co-ordinated by the Chief Controller who should be assisted by an Advisory Committee composed of nominees of the Research Advisory Council and the Director of the Research Units.

An immediate programme for the Research Units would include:

(*a*) Survey of coal resources.
(*b*) Coal mining.
(*c*) Coal handling and transport.
(*d*) Industrial use of coal, particularly steam generating.
(*e*) Domestic fuel production and utilisation.
(*f*) Conversion of coal into high value products.
(*g*) Research into liquid fuels from tropical vegetation.

The objectives of the work would be to:

(*i*) Use our coal seams to the best advantage.
(*ii*) Increase the efficiency of utilisation.
(*iii*) Create new industries using coal as a raw material for high value products for export.

The research and development activities of the Scientific and Technical Service of the Fuel and Power Research Units should be supplemented by the placing of research and development contracts, both with university departments and with firms manufacturing machinery and equipment. In the Ministry, the Scientific and Technical Division should be supplemented by scientific Advisory Committees and panels so that the advice of the best experts available on any problem should be made available to the Minister.

Upon an organisation such as this a better future for the fuel and power industries can be built.

4

KEY INDUSTRIES OF BRITAIN

II: HEAVY CHEMICALS

THE RAMIFICATIONS AND IMPORTANCE OF THE INDUSTRY

THE heavy chemical industry is concerned with the large-scale transformation of materials into substances used in almost every other industry. In Britain, it is based largely on: (*a*) native raw materials, such as coal, salt, gypsum, limestone, clay; (*b*) imports such as sulphur and pyrites, phosphates, potash salts, vegetable oils, molasses, etc. From these materials are made products essential to such industries and services as: iron and steel production, non-ferrous metallurgy; engineering; building and construction; agriculture; transport; textiles; food and drugs; electrical gear; paper-making and printing; public health services and sanitation. By-product manufacture and waste-utilisation in a number of staple industries also come within its scope, e.g. slag by-products for fertilisers; cement and refractories from the steel industry; fertilisers; solvents, plastics, dyes, explosives and fine chemicals from the gas and coke-oven industry. As both a producer and a consumer of raw materials, the chemical industry is of strategic importance for planned reconstruction. As the creator of substitutes and of means of using native deposits of raw materials and wastes, the chemical industry could be a main factor in reducing imports. This broad view of the place and scope of heavy chemicals within industry as a whole is essential to any consideration of national resources. It must also be borne in mind that the scope of the industry is continually widening with regard to the materials and techniques used in other industries. Examples of this may be found in its interlocking relations with artificial textile manufacture and with oil-refining to provide the raw materials for the large-scale production of organic chemicals. The war has accelerated this process by the enforcement of economies and the use of substitutes, alternative starting-materials and entirely new methods. Many of these new developments have come to stay. This refers not only to ventures which have attracted attention in the technical and general press (e.g. plastics and magnesium) but also to revised methods and principles of conservation adopted in making established and even common products of the industry, e.g. sulphuric acid, fixed atmospheric and other nitrogen, coal and steel by-products. Legislation is still required to prevent avoidable waste of materials. It is also essential to prevent a wholesale jettisoning of useful home raw-materials, used during the war, in favour of traditional imports. Some of the fields in which a national policy is required are reviewed below and lines along which the main technical problems can be overcome are suggested. The topics treated are of outstanding importance in this key industry, but are by no means the only ones.

POSSIBLE ADVANCES IN COAL-CARBONISATION BY-PRODUCTS

Coke-ovens and gas-works through their by-products yield a substantial proportion of heavy chemicals, and this is capable of expanding even without alteration of the present consumption of 40,000,000 tons of coal per year. By the general introduction of careful management the quantities of material recoverable are as follow:

	Tons per year
Ammonia	107,000 =430,000 tons of sulphate
Sulphur	214,500 =600,000 tons of sulphuric acid
Benzol (benzene, toluene, etc.)	500,000
Naphthalene	80,000
Phenols	65,000

The pre-war recovery of ammonia (largely as ammonium sulphate for use as fertiliser) was incomplete, since the home consumption of all nitrogenous fertilisers was equivalent to about half the above figure for ammonia (107,000 tons per year) while exports were largely derived from the fixation of atmospheric nitrogen. Together with the greatly increased production of fixed atmospheric nitrogen, by-product ammonia recovery offers a large surplus for export to help in European reconstruction. Of the recoverable sulphur, only about one-third was used, as spent-oxide, in acid manufacture; complete utilisation would cover half the home requirements of sulphuric acid, i.e. the quantity used in the steel and fertiliser industries. Little more than half the possible benzol was recovered; the institution of compulsory recovery would itself secure a large increase in the materials required for various plastics. It is probable that modified carbonisation methods or intensified hydrogenation of coal would be necessary in order to obtain essential increases in the production of benzene, toluene, naphthalene, phenols, etc.

Direct methods of using coal as a chemical would include: (1) modified methods of hydrogenation to give increased outputs of gaseous paraffins, phenols, aromatic hydrocarbons and bases, or even exclusively these, instead of motor-fuel; (2) production of calcium carbide for acetylene and for cyanamides (the latter for fertilisers and derived plastics); (3) works-scale development of coal-oxidation processes for dibasic acids to be used in plastics.

There is no doubt that war-time technological advances in the application of plastics will lead to a greatly increased tonnage of the materials needed in their manufacture. Where synthetic plastics replace natural raw-materials this is likely to be because they possess more desirable properties for specific purposes rather than because they are cheaper weight for weight.

SULPHURIC ACID

The production of sulphuric acid is one of the oldest large-scale chemical manufactures. The scale of any one producing-unit is, however, limited by the demand in the immediate vicinity, owing to the cost of transporting this corrosive fluid. The total production in 1938 was nearly 2,000,000 tons of 70 per cent acid or 1.36 million tons calculated as 100 per cent acid (H_2SO_4). About one-third of this was used in the production of superphosphate and ammonium sulphate for fertilisers and about one-tenth for steel-pickling. The remainder finds numerous large-scale uses throughout the chemical and related industries. Nearly 70 per cent of production was from imported pyrites and sulphur; a further 12.5 per cent came from zinc ores. Only 19 per cent was produced from spent-oxide; complete utilisation of spent-oxide from gas-purification could have accounted for 45 per cent. The production of sulphuric acid from calcium sulphate, with a convenient equal output of cement, though economically attractive, was relatively insignificant. Other neglected sources are recovery from: spent pickle-liquor; coke-oven and gas-works crude ammonia liquor; sewage treatment on the Mogden pattern (which would, incidentally, secure large tonnages of methane). These possibilities are of course not new; spent-oxide is already largely used, cement and acid-production from calcium sulphate is operated in one large unit in Britain, pickle-liquor recovery is practised by the Chemical Corporation in the U.S.A., and small installations for making sulphuric acid from hydrogen sulphide are operated in this country. An excellent case therefore exists for the direction on a national scale of the utilisation of sulphur-bearing materials towards the following ends: (1) complete utilisation of spent-oxide; (2) increased production of sulphuric acid (and cement) from native calcium sulphate; (3) more complete use of sulphur wastes from pickle-liquor, coke-oven and gas-works liquor and sewage;

(4) compulsory treatment of sulphur dioxide fumes from smelting and other operations (leading incidentally to an important diminution of atmospheric pollution).

FERTILISERS

The three main plant-foods supplied in fertilisers are phosphates, potash and nitrogen; calcium, which plants also need, is supplied separately, as burnt or hydrated lime, ground limestone or chalk. The full use of the potential by-product ammonia and of the war-time expanded atmospheric nitrogen-fixation factories could ensure a large exportable surplus of nitrogenous fertilisers to necessitous countries. Imports of phosphate and potash into Britain on a large scale are inevitable, although the use or development of national resources is possible and probably necessary. In general, the pre-war consumption of fertilisers in Britain was extremely low; war-time improvements in agricultural practice have enabled a greatly increased use of fertilisers to play a major part in the restoration of the fertility of British soil; this policy needs to be continued in the future.

Phosphates. Superphosphate fertilisers were first introduced by Lawes in Britain a hundred years ago, the manufacture being from native deposits of coprolite, phosphorite or phosphatic chalk. The working of outcrops and drifts down to 20 feet below ground secured, in 1876, over a quarter million tons of what would now be called low-grade rock. In the subsequent twenty years the mining of British phosphates became virtually extinct because of the import of fluorapatites, richer in phosphorus and less scattered in distribution than British phosphates, from North Africa and Florida. Contributing to this decline of home production was the royalty approximating to 10*s*. per ton imposed on mining the British material. But for this and the restrictive tendencies of the superphosphate manufacturers, modern mechanical methods of handling shallow deposits, coupled with the use of flotation, etc., could have secured some resumption of mining in this country.

In 1939, world production of superphosphate was about 17,000,000 tons, two-thirds of which was located in Europe and only 560,000 tons approx. in Britain. By 1942 world production had shrunk to some 12,000,000 tons, a fall of tragic significance for the post-war problems of feeding a war-devastated world and for long-term problems of soil rehabilitation. There can be no doubt that the Hot Springs policy requires from Britain both a continued intensification of agricultural production and the creation of exportable surpluses of fertilisers.

The main forms of phosphatic fertiliser used are superphosphate and basic slag from steel manufacture. The use of bones in the manufacture of superphosphate is relatively small (50,000 tons per year, of which about ⅘ is imported). Basic slag production in Britain was over half a million tons in 1938, compared with the 5,000,000 tons of world production. This indigenous material could be made more valuable by the control of the fluorspar addition to the furnace, since it is probable that the presence of fluorine reduces the availability of phosphorus to plants. The question of what is the most economic form of phosphatic fertiliser has been studied during recent years and methods of treating phosphate rocks other than by the superphosphate process have emerged, e.g. alkaline heat-treatment, kiln and furnace methods.

There is an undoubted need for a greater application of phosphatic fertiliser to British soils. About 30,000,000 acres were farmed in 1937 for crops and pasture; the proportion of arable acreage has been increased by war measures. The maintenance of the arable acreage will require a substantial increase in phosphate manufacture, even at the pre-war level of application. Permanent grassland also requires fertilisers, e.g. Stapledon has estimated that 575,000 tons of additional basic slag could be employed per year in improving three-quarters of our permanent grassland. The steel industry, expanded to meet the needs of reconstruction, could only meet the full requirement of basic slag if its output were doubled; any lesser increase in basic slag production could easily be absorbed in carrying out a correct manuring policy for permanent grassland. Basic slag is, of course, a by-product merely of one particular method of steel production; modern developments in the steel industry are likely to decrease, rather than increase, the production of suitable types of slag.

The application of superphosphate at an average rate of 2 cwt. per acre on only 10,000,000 acres would require a million tons per year, i.e. twice the pre-war consumption. There is thus need to use other sources of phosphorus. The development of the use of properly prepared sewage-sludge would help in a small way to meet the need, and a resumption of superphosphate manufacture from British minerals is also important.

All these questions should be regularly reviewed as further knowledge is gained about increasing the availability of manufactured phosphates to plants. At present, it is likely that only some 25 per cent of the phosphate applied is taken up by the crops, the remainder being fixed by the soil in unavailable form. Clearly, great returns for the nation are to be expected from a moderate increase in this figure of availability; large-scale research, including investigations on fertiliser placement in the soil, should be directed to this end. The phosphate industry presents another good case for State intervention with a national policy, since there is no other way of integrating the diverse interests involved, which include superphosphate manufacturers, the largely unprogressive steel industry, regional sewage disposal, land rights, agricultural planning in the light of the Hot Springs Conference, and the co-ordination of research directed to seeking alternative and more efficient treatments of phosphate minerals.

Nitrogen. Before the war about 250,000 tons per year of ammonium sulphate and 50,000 tons per year of other chemical nitrogenous fertilisers were used in Britain. This quantity of nitrogen fertiliser could be doubled or trebled while still yielding an economic return from the increase in crop. The increased quantities of available nitrogen which could be expected to result from legislation to ensure by-product recovery from coal have already been mentioned (p. 54). The large government sponsored war-time increase in the fixation of atmospheric nitrogen should not be allowed to lapse through restrictive operations by private "enterprise," but should be maintained to help in fulfilling the real national and export requirements for nitrogenous fertilisers.

Potash. Britain has been almost entirely dependent on imported potash, the only home materials available being the intractable felspar, clay, etc.; but polyhalite, according to recent American and Soviet work, is a possible source. The extraction of potash from sea-water should also be investigated. Over 200,000 tons per year of various potassium salts were imported before the war, but there has been great shortage since 1939. In spite of this, projects for potash extraction from felspar and polyhalite have not progressed. There is an obvious need for a review of, and research into, home resources as part of a long-term process of increasing potash supply and consumption. It is probable that increased imports of potash will be essential in the post-war period, especially for the increased acreages of vegetable crops needed to improve the level of nutrition in Britain.

Lime. There appears to be no doubt that the use of lime for agriculture should be greatly increased. This is in part an educational problem: too many farmers neglect liming, especially in the wetter areas. Much lime is necessary for the reconditioning of acid land as well as for the current needs of agriculture and industry. Stapledon estimates the additional requirements at 1.4 million tons per year as burnt lime, or 2.4 million tons per year of limestone and chalk. The provision of even a fraction of this quantity will require government co-ordination of the industry, technical improvements in production and mechanical distribution of the material, all on a scale which appears to transcend the outlook of the industry at present. The prime difficulty is the continuance of the technically obsolete process of burning lime, which has been a bottleneck in production, while hard steels have for forty years made it possible to grind raw limestone. There is no evidence that, for general agricultural purposes, burnt lime is in any way superior to the ground rock, except perhaps where rapid action is required. The expansion of lime production should therefore be based on limestone grinding, and on the use of ground-chalk which can be easily and cheaply obtained in many parts of the country. There is great need for research on the liming of soils.

OTHER TOPICS

Other aspects of the heavy chemical industry which cannot be treated here include: iron and steel production, light metal production, the soda and chlorine industries, fat, sugar, cement, gas liquefaction industries, and sewage and refuse disposal. The above indications of some of the ways in which a few fields of heavy chemical industry could meet the requirements of a developing and expanding economy should illustrate the very great need for development throughout the whole group of industries.

RESEARCH REQUIREMENTS

These, for chemical industry as a whole, are very similar to those in the fuel and power group: (1) greater understanding of the fundamental physics and chemistry of the various raw materials; (2) new and improved industrial processes. The first requirement will be met, to a great extent, if the plans envisaged in Chapter 13 are put into effect. The second requirement chiefly involves the development of good schools of chemical engineering in Britain. The general standard of this subject at present (except within a very small number of undertakings) is deplorably low, and may be ascribed, in part, to the very limited facilities for obtaining training as part of post-graduate education. The pressing need for chemical engineers has led to the Ministry of Education arranging intensive twelve-month courses in Technical Colleges (1946). Plans for a permanent increase in the number of courses in chemical engineering are also essential. A great expansion in teaching and research in chemical engineering must be secured. In the past, Britain depended largely on processes developed abroad; this cannot be regarded as satisfactory. The factors which set the chemical engineer his problems are different in every locality and call for the highest ingenuity in achieving solutions. Britain must be able to train her own chemical engineers in order to be able to develop her own economy adequately.

5

KEY INDUSTRIES OF BRITAIN

III: ENGINEERING, TRANSPORT AND COMMUNICATIONS

THE ENGINEERING GROUP OF INDUSTRIES

The Position of the Industry. This very large group of industries has special significance for the arguments of this book. These industries are frequently the last link in the chain connecting scientific research with the user; inefficiency in them can therefore frustrate the utilisation of science in bringing a better life to the mass of the population. Although they are also producers of consumer-goods, the engineering industries are of primary importance because they produce the tools and mechanisms on which nearly all other industries depend. They are the supreme producers of capital goods; as such they are bound to be closely related to national and international planning.

The degree to which many major industries in Britain are in need of equipment replacement and modernisation has already been stressed. Throughout Europe there is tremendous devastation and lack of essential transport and power supplies. Some indication of the scale of capital development necessary in some of the major undeveloped or partially developed countries has already been given. The war-expanded engineering industries of Britain and its allies present excellent opportunities for meeting the needs of reconstruction and development. To do this will involve changes in Britain's industrial structure and export trade. The developing countries will tend to produce consumer-goods, and for this they will need plant and equipment. While this may mean a decrease in Britain's exports of certain goods, such as textiles, there should be a more than equivalent rise in the export of engineering products, the machines and plant needed for the new industries. It is in industries such as engineering, which have highly developed techniques and which are dependent on trained technicians and skilled workers, that the older industrial countries, with their greater experience, are likely to achieve the high relative efficiency which must be the basis of satisfactory and enduring trade relations.

Production Methods and Standardisation. The most important single problem before the engineering industries in Britain is the relating of development and design to efficient production, i.e. designing for production. It is well known that, in spite of higher wages, most engineering products are cheaper in the U.S.A. than in Britain. The reason is partly that each individual firm in the U.S.A. has a larger output than have corresponding firms in Britain, and so can make profitable use of more advanced production methods involving a wider use of complex automatic machine-tools. The problem in Britain is thus to secure the advantages of the most modern and economical production methods. To achieve this, and thus to put the engineering industry fully at the service of the community, the correct policy appears to be to continue in modified form the war-time technical controls, with special reference to the standardisation of components and to the concentration of production. In the electrical-machine industry, for instance, there is very little to choose between a motor of given rating made by one manufacturer and that of another; yet, for reasons of commercial competition, they are all made different in appearance. Since each manufacturer has only a moderate output of each particular machine, it can only be made by semi-handmade methods, with consequent high cost. Under a rational system, even within the framework of privately owned industry, a technical control body would standardise designs of machines for each of the common ratings and allocate production to different manufacturers, so that machines of each design could be made in sufficient quantities to permit the economic use of mass-production methods at a high technical level. These arguments apply equally to the mechanical engineering industry.

Machine-tools and Manufacturing Methods. This is a topic of major importance. The position has improved since the beginning of the war, but it is not enough that some leeway has been made up; further development is essential. The study of the technique of manufacturing methods has not in Britain anything like the status it has in the U.S.A., where it figures conspicuously in the curricula of universities and technical colleges. Recent developments in metallurgy, the technique of welding, the use of plastics and ceramics, all demand a new orientation. The increasing use of automatic methods is right and inevitable, but it raises the spectre of "technological unemployment." In an economy planned for full employment, however, there is no reason why repetition-tasks, which can be performed more rapidly and more accurately by automatic machines, should be carried out by human labour.

The idea, sometimes entertained in Britain, that British products made by hand are inevitably in some way superior to American mass-produced articles must be abandoned. This war has shown that American manufacturing technique can produce good articles cheaply and can also make things with machines which cannot be made by hand at all. Through the development of scientific production with precision machine-tools, the Americans have produced, on a large scale, precision gun-control mechanisms which no British manufacturer could make except in the tool-room, and which could not then be made in quantity in Britain. This concentration on production problems would raise a large number of new research problems, particularly in the production of materials which lend themselves to rapid production of precision parts.

Durability. A further factor which needs consideration is the assessment of the useful life of any given article or machine. It is one thing to take a pride in building to last, but it is quite a different matter if price-levels thereby established handicap the user in planning a reasonable policy of obsolescence and supersession. Machinery in a rapidly growing and changing industry may, if built with too much attention to long life and too little to first cost, be a serious impediment to the maintenance of efficiency. In some sections of British engineering (e.g. agricultural machinery) the mistake has been made, in the past, of combining in one machine parts built to last a lifetime with parts so indifferently designed that breakdowns repeatedly occur.

Scientific Organisation. Although, in large sections of the engineering industry, levels of manufacturing technique are high, much improvement is possible; for instance, the automobile section has still to solve the problems presented by really large-scale production. In recent years too many of our industries (e.g. the electrical industry) have relied for much of their research and development on their American associates. It is obviously in the national interest that British industry should be able to stand on its own feet, with technical staffs the equal of any in the world. Except in some of the older and more "traditional" sections, the individual designers and technicians need not fear comparison with those of any other country; but, if the industry is to meet post-war needs, there must be a very considerable increase in numbers, better facilities and enlightened and imaginative direction. In particular, the problems of the re-equipment of basic industries will demand close co-operation between widely different sections of engineering on a scale which has proved beyond the resources of isolated and relatively small units. Some of these matters may be handled by enlarged and energetic research associations, but they will also involve consulting, advisory planning and economic studies. In many cases these tasks could be adequately dealt with by the existing industrial staffs, provided that proper co-operative and central co-ordination were achieved. There would appear to be scope here for the establishment of central authorities to examine the problems of some of these industries and to co-ordinate the work of the sections of engineering industries capable of solving them. The way in which the appropriate controlling groups co-ordinated the requirements of the fighting services and industry during the war, by means of "development controls," may indicate a method.

A word of warning concerning reports of the interchange of technical missions with the U.S.A. is appropriate here. It is not sufficient, in a wave of enthusiasm at the sight of certain American achievements, to call for the copying of their methods over here, or alternatively, to swing to a mood of depression at the discovery that some of their methods cannot be applied. What is needed is that the lessons of American experience should be applied to the evolution by British scientists of methods appropriate to British conditions. It may be that certain methods of American coal-mining mechanisation are not applicable to the existing mines or types of seam in Britain. It is wrong, however, to conclude from this that the development of mechanisation should be abandoned; the development of techniques suitable for British conditions is what is needed. Similarly, much American agricultural machinery is too wide for British lanes and gates; but that is no reason for not developing suitable counterparts and novel machines suited to British conditions. In much of this work the old concept of scientists as inventors of new machines or devices to be sold to an eager and expectant public is becoming superseded. The engineer applies the more or less completely known principles of a complex and steadily expanding technique to the logical and systematic solution of the problems presented to him. The task before industrial organisers is to present the right problems in sufficient completeness of detail to the right people and to see that no obstacles prevent the mutually interested parties hammering out the solution.

In the light of this general summary, it is worth while to examine one or two particular branches of the engineering industry in somewhat greater detail. No attempt will be made to do more than examine some typical examples.

ELECTRICAL ENGINEERING

Future demands on the electrical engineering industry will be enormous and much greater standardisation of components will be imperative, both to secure high output at far lower prices, and to facilitate maintenance and the stocking of spares. The standardisation of motors, transformers and transformer stampings was developed during the war. The number and variety of types of transformer stampings were formerly grossly excessive. This question of standardisation will be increasingly important, from the users' point of view, in the hoped-for extension of electrification and use of electrical machinery in rural areas and in farming practice. The fact that such a powerful ring as the British Electrical Manufacturers Association has not achieved more along these lines is an indication of the negative character of the control deriving from such an uneasy defensive alliance, and of the need for national direction.

In research, the existing Electrical Research Association in its 1943 report indicated a total income of only £120,000. It is difficult to assess the amount of money spent on research by individual firms, but it is evident that the amount of money available for this co-operative Research Association represents only a quite insignificant fraction of the total turnover of the industry. The contribution from supply undertakings amounts to only $\frac{1}{1000}$ of their revenue. This is clearly far too little for an Association which should, in addition to its obvious fields, either execute or foster much research in metallurgy and the applications of plastics and ceramics in the electrical field. There is a need for some central body to share in the evaluation and solution of the problems likely to arise from the proposals for an integrated policy on fuel and power (see p. 31 *et seq.*).

THE AUTOMOBILE INDUSTRY

Before the war this was one of the three largest industries in Britain; during the war part of its capacity was turned to aircraft work, and the total capacity now controlled by the firms in the industry has expanded enormously. There should be no difficulty in using this capacity in the immediate post-war period; the problem will be how best to fulfil the great demand for vehicles which is arising from war-stricken Europe and elsewhere. The Soviet Union alone, it is said, will require 20,000,000 vehicles. There will also be need for an increasing number of vehicles if the backward countries are to be developed. For the British industry to play its part, it is necessary that the many factors which precluded it from any large share in overseas markets before the war should be removed. The cost of a British car was higher than that of the U.S.A. product; 65 per cent of this cost was due to raw material and fabricated material costs. The price levels of two-thirds of this percentage were maintained by rings, combines and cartels; steel in particular cost the British industry 50 per cent more than the American. To this extent the future of the industry depends on a lowering of raw material costs. Within the automobile industry there is scope for considerable improvements in efficiency by the adoption of production methods which have long been in use in the U.S.A. There may be mentioned: the use of radiant-heat plant for drying paints, enamels and foundry moulds; induction-hardening to produce surface-hardening of steel components; electric-welding for unit body construction; negative-rake milling for machining; electromagnetic methods of crack detection, to ensure greater reliability of parts.

Wasteful practices, which arise largely from the methods of competition between different firms, should go. Before the war, selling-costs were enormous, amounting possibly to 40 per cent of the selling price. A bad influence was the Annual Motor Show; competition caused firms to make annual superficial changes to their designs in order merely to catch the public eye. More serious was the seasonal unemployment which resulted because, as the Show drew near each year, the public would wait for the new models, and thus work slackened until after the Show. Research equipment, laboratories and technical staff were quite inadequate. Firms would quite often rely for their new designs on stripping and examining American models; very few firms even had laboratories equipped sufficiently to control technical and manufacturing processes.

As a policy for the automobile industry, there should be urged: removal of the inadequacies mentioned, the elimination of price-rings and seasonal employment (by State action if necessary), the use of new techniques and a great increase in the scope of research. The basis of motor taxation should be further changed, so that the type of car produced for the home market will be readily exportable. It will be impossible for British industry to achieve the production necessary for the efficient use of new techniques unless it can continue to export after the immediate post-war demand has been met. Finally, luxury models, whose high cost has been due more to inefficient methods of production than to quality, should not be produced until the urgent needs of devastated regions are met.

The automobile industry should undertake serious concerted studies of customers' requirements and of required performance under service conditions, of commercial, agricultural and other types of vehicle for export. Modification of the taxation basis alone will not cause alterations in design so that the product will sell abroad. All the complex problems of rough roads, extremes of climate, infrequent supplies of fuel, must affect the designs of vehicles for export.

THE AIRCRAFT INDUSTRY

This industry was tremendously inflated by war requirements and its production has now much decreased. The aeroplane cannot compete economically with other means of transport, except in the few fields where high speed is particularly valuable: mail-services, some grades of passenger transport and transport of goods of very great value per unit weight. It may be anticipated that, for reasons of prestige, and for the military advantage to be assured by the existence of a large and efficient civil aircraft industry, states will maintain civil aviation by means of subsidies at a higher level than economics alone would dictate. But, here again, the military requirements would be modified by the existence of a world security organisation. Some experts have estimated that the demands on the productive capacity of the industry after the war will be about 10 per cent of war-time capacity.

The maintenance of civil aviation by Britain, and the endeavour to keep British-produced aeroplanes up to the best level of those made abroad, will nevertheless require almost as much research as is at present devoted to military types. This is because Britain has been specialising in military aviation, and even before the war a Government Commission on Civil Aviation reported that British manufacturers were far behind the Americans in the civil field. Work will have to be done to increase safety and reliability; further research is required on pressure-cabins, and on radio and other navigational devices. Considerable work must be done on aero-engines. Gas turbines driving airscrews are the most promising development for the power units of civil machines. Their design is simpler than that of reciprocating engines, and it will be possible to build units reaching powers hitherto impossible. They will be lighter and probably more reliable than reciprocating engines. Gas turbine development will require a considerable amount of aerodynamic and thermodynamic research, and also continued metallurgical research on alloys capable of withstanding stress at high temperatures.

At present the main firms in the aircraft industry are organised in the Society of British Aircraft Constructors; before the war this was a ring which practically monopolised State orders. The industry has no research association, and relies on State institutions to carry out research for it. Even within individual firms it is unusual for research work to be undertaken unless it is paid for by the State.

If the industry remains in private hands the circumstances will be such that large amounts of public money will be spent on research equipment and a training college for the industry, whilst the private firms at little risk and comparatively small capital investment receive profits from the sale, mainly to the State, of equipment which they have designed, and perhaps built, with State funds. In these circumstances it is difficult to see what positive role is played by private ownership of the industry—the administrative side of which is notoriously inefficient.

HEAVY ENGINEERING

This industry covers a wide and complex field and it is difficult to touch on more than one or two outstanding points. In general, the war produced an increase in the manufacturing capacity of the industry, but disturbed its balance. The process of re-adaptation demands foresight, imagination and co-operation. With regard to shipbuilding there can be no doubt about the importance of the Royal and Merchant Navies to the well-being of the country. The former emerges from the war in a stronger position than ever, both in ships and in trained personnel. The Merchant Navy, however, is very weak compared with its pre-war strength, in spite of war-time building. Only about half the tonnage afloat at the beginning of the war has survived; some of these vessels are old, with engines of poor efficiency by modern standards. This position is not due to sinkings only, but also to the fact that production in shipyards has been concentrated mainly on ships of war. There should now be no difficulty in greatly increasing merchant-ship construction.

Before the war, merchant shipping had tended to develop more and more towards the running of definite routes rather than on the tramp trade, though the latter must always be of considerable importance. A ship designed for a particular trade should always be better for that trade than one built for general purposes. It is likely, therefore, that a large number of special-purpose ships will be required; the many different types required will reduce the possibilities of using mass-production methods. Among vessels of special type are the carriers of perishable food-stuffs, e.g. fruit and meat; these should be given high priority. It should be the business of some authoritative body to allot these priorities to the best advantage. The development of new designs would provide excellent opportunities for vastly improving the accommodation for crews.

Propelling-machinery seems likely to develop without outstanding changes. Steam-turbines with high pressure water-tube boilers and oil-motors are making steady headway in efficiency and in decreasing weight. There is still a useful though diminishing field for the steam reciprocating engine. The internal-combustion turbine is still in the experimental stage, and its progress probably depends more on the metallurgist than on the engineer. Welding is likely to play a greater part both in the construction of engines and ships; there is a need for considerable research here.

LOCOMOTIVES AND RAILWAY ROLLING-STOCK

This field must be considered from three points of view: the urgent need for re-equipment and modernisation of rolling-stock on British railways, particularly in respect of goods transport; the heavy demands of European rehabilitation; the probable scale and rate of the move towards electrification. The vast amount of work involved in establishing even the basis of a reasonable transport system in the less developed regions of the world means a big export market for many years to come. Much effort will be needed to assess and to analyse the special requirements of various countries, but, since "the customer" tends to be a state-controlled or large-scale utility organisation, the initiation of much of the exploratory work will tend to start at that end. This will, however, be one of the many fields where industry will need to organise a service of technical assistance to the rapidly-growing operating organisations. Much of the industry's success will depend on its ability to provide sound, up-to-date and objective advice and on having the necessary resilience and imagination to profit by the experience acquired.

LIGHT ELECTRICAL ENGINEERING

The obvious major fields for examination are the radio and communication industries. In certain fields these industries had a large degree of war-time inflation owing to the immense production of radio-communication, radiolocation and navigational-aid equipment for the Services, as well as a vast amount of line plant and associated equipment for signals. On the other hand, switching-equipment manufacture was heavily curtailed, and there is much leeway to make up. There are many areas at home and abroad where shortage of equipment is acute.

The provision of domestic radio-receivers will be a mass-production problem; a high level of standardisation will be necessary. The potential productive capacity of the industry is enormous, probably 4,000,000 to 5,000,000 sets *per annum* without strain. It will therefore be necessary to ensure that too large a proportion of the industry does not concentrate on this aspect and that production efficiency is maintained at a level which will provide favourable price comparisons in the foreign market. Any estimate of the probable volume of sales of radio-receivers must take account of the need for radio as an educational aid in a Europe desperately short of text-books. For much of this, and in the general domestic field, what is wanted is cheapness, reliability and adequate performance, without unnecessary frills. There will be a big field for the application of radio-location and navigational-aid devices in post-war shipping and air transport; the application of thermionic devices for use in land-transport and in railway signalling will need careful investigation.

The development of the radio industry in recent years has led to developments in other fields, e.g.: the application of radio-frequency energy to the heating of materials, as in the manufacture of resin-bonded plywood; the rapid case-hardening of metals; medical applications such as diathermy, cautery and encephalography; in scientific research in general. In nearly all these fields there is a danger of empiricism and skimped research unless their importance is adequately recognised and the appropriate co-ordination and co-operative effort secured.

Electronic methods and the basic principles of telephone-switching can provide solutions to many problems related to the automatic control of processes, remote-control, indicators, calculating and computing. These and many similar issues present the difficulty of the need to plan effective research and development on lines which tend to cut across the present general commercial pattern of the industry. The shape of many industries is largely controlled by manufacturing considerations, and technical by-products tend to be shelved as not fitting the commercial plan. Research Associations should be able in a measure to solve these difficulties, but only if the industry widens its outlook and shows a more co-operative spirit.

TRANSPORT AND COMMUNICATIONS

Britain has a great tradition as a leader in the merchant shipping of the world. It is doubtful whether its supremacy will be maintained but, with the degree of expansion in world-trade which is to be anticipated, there is no reason why the quantity of international traffic handled on British lines should not increase. Cheap, reliable and fast long-distance transport will be imperative to the maintenance of our trade. With a growing tendency towards the industrialisation of regions at present under-developed, and with the expectation that many British industries will be able to develop expanding trade-relations with these developing areas, it is clear that the efficiency of transport to these regions must be as great as possible. No pains should be spared to ensure its technical consummation. Apart from the actual problems of hull design and provision of engines, etc. (see p. 72), the supreme importance of modern methods of goods-handling in docks and harbours and the need to co-ordinate inland and overseas transport must be stressed. Interesting possibilities are opened here by war-time developments in the design of special landing-craft, with their entirely unconventional methods of access to the interior of holds, etc.

The more enthusiastic advocates of overseas air-transport paint a glowing picture; even allowing for undue enthusiasm it must be conceded that for certain types of transport it will have an important future. On trans-oceanic passenger service the cost in horse-power per passenger may at first sight appear damning but, if allowance be made for the shorter duration of the flight, the total expenditure of work per passenger is not fantastic and compares favourably with the "one man" car on the road. The handling of perishable goods, mail, and goods of very high value per unit weight should provide opportunities for economic exploitation. In lightly-populated large land-areas the use of aircraft in connection with health and medical services is likely to be developed; also for pest control.

In Britain itself the whole transport system requires much greater co-ordination than has so far been secured in peacetime. A planning body, with some of the powers of, but a wider scope than, the Ministry of War Transport, is needed to analyse the whole problem of Britain's traffic requirements, to determine the most effective use of various types and to relate progress to the general problems of town and country planning, industrial dispersal and rehabilitation. The present conflict between road and rail interests must submit to control: it is not enough that a state of semi-neutrality should be achieved by parcelling out traffic between them on the basis of the present unplanned interrelation. They must be regarded as complementary and the best joint working should be secured. This may mean long-term planning, with major repercussions on the location of goods termini, marshalling-yards and the layout of road-systems.

The problems with the railways are largely economic and financial. As with many old-established industries the railways appear now to be paying the price of injudicious policies in their earlier days. There was a failure to establish sufficiently high rates of amortisation; now the industry is saddled with vast assets tied up in obsolete premises, plant and equipment. The financial position of the railways needs overhauling by public authority; it is difficult to see any valid case against national control. On purely technical questions the main tasks in rail-transport are related to improvements in the speed and efficiency of goods-handling. The efficient use of tracks and the maintenance of high speeds and punctuality on passenger services are dependent on much greater uniformity of train-speeds than at present achieved. There is urgent need for a great increase in the quantity of fast continuously-braked goods rolling-stock. On four-way tracks the slow goods-train can be fitted in without too much difficulty but with twin tracks it is a highly disturbing factor. There is a great need for further development in the mechanised handling of freight at terminals and points of transhipment, and for further application of such ideas as the road-rail "container" system. The quest for higher speeds and more train-miles will also require a review of signalling technique. The crack flyers of the pre-war period had already reached the stage where the speed-limitations were not so much a matter of haulage as of the incompatibility of really high speeds with the traditional block-system of signalling. The railways are rightly jealous of their magnificent safety record, but there would appear to be room here for considerable technical advances without relaxing any of the safeguards.

For haulage, the trend will inevitably be towards electrification. Apart from the advantages of electrification in respect of fuel-efficiency, estimated in the Weir Report as saving 9,000,000 tons of coal per year, other great benefits to be derived are greater cleanliness and the reduction of smoke-damage in populous areas. The relation of railway electrification to the general problem of rural electrification must be considered in any further studies of the economics of main-line electrification.

Road-haulage has made immense strides in recent years, thanks to technical advances in design of power-units, chassis, braking systems and tyres; undoubtedly, the experience gained in the construction of specialised war-transport can be turned to advantage. One primary task should be the construction of a trunk-road system, kept clear of all the obstacles and frustrations of ribbon-development, etc., which have thwarted earlier efforts.

There is a temptation to seek for speed and to regard inland water-transport as moribund. Canal transport has, however, strong claims in the handling of heavy non-perishable traffic, such as china-clay to the Potteries. Here the tasks ahead concern civil engineering, reinforcement of banks against erosion due to motor-barge traffic, modernisation of locks and, perhaps, the replacement of some chains of locks by large-scale lifts.

Britain's telecommunications are, on the whole, in a healthy state. Figures are sometimes given to show our deficiencies as compared with the U.S.A. in the number of telephones per unit of population, but that criterion is not everything. The General Post Office had established an efficient and reliable service before the war. But considerable efforts will have to be made if it is to cope adequately with the rapid expansion in prospect. In particular, the potential demands on trained personnel of the ever-growing maintenance problem must be faced. The close relation of telecommunications to transport development is obvious: The introduction of air-transport and the modernising of rail-transport will be seriously handicapped if their dependence on first-rate telecommunication facilities is not adequately recognised.

6

KEY INDUSTRIES OF BRITAIN

IV: AGRICULTURE

THE WORTH OF THE LAND

BRITISH agriculture represents only one aspect of the general problem of providing food for the people of Britain but, for reasons of space, the problems of fisheries, for example, cannot be discussed here.

A consideration of British agriculture also has a bearing on the problem of land use. The people of Britain live mainly in towns, and the countryside has great importance to them as an amenity, as a place of relaxation and recreation. One must be aware, too, of the intellectual, educational and cultural advantages which spring from a knowledge of the countryside. In short, the countryside being a valuable asset, its adequate preservation is a matter of national importance. Further, a good countryside from these points of view is a well-farmed countryside: to allow it to revert to a condition of weedy and overgrown dereliction is unthinkable, though economic considerations may, in the remote future, demand the retrenchment of considerable "marginal" areas. No one can measure the economic value of an amenity but, equally, no one can doubt it. There would thus be a case for the expenditure of labour or money in maintaining the countryside, even though it may not, theoretically, be economically necessary. This is no argument for the retention of obsolete modes of production or ways of life. It is, however, a plea for the preservation, even at an apparent book-keeping loss to society, of the British countryside, both from unplanned urbanisation and from wasteful dereliction. Allied to this is the question of afforestation. The planting of forests on some of the land not required for farming is a correct policy, but the decisions to afforest or not to afforest should be based on a national plan for land use, and not merely on local convenience or on compromises between conflicting sectional interests. What is needed, then, is a national outlook on land use which apportions land as it is required from time to time, remembering always that the non-economic needs of an urban population have a right to consideration in the general plan.

THE ADVANCEMENT OF AGRICULTURE

Food Production Policy. The future character of international agricultural policy was foreshadowed at the Hot Springs Conference and in the constitution of the International Food and Agriculture Organisation to which the Conference gave rise. The Conference called for an expansion of food production to the level where hunger and bad nourishment will be banished from the world and an economy of abundance attained. Agricultural policy, in other words, should be determined by nutritional needs. The increases in food production required by this policy, taking the world as a whole, are tremendous. It has been estimated by the U.S. Department of Agriculture that for cereal production the necessary increase is of the order of 50 per cent, while for other foods the figures range up to several hundreds per cent. A world policy on this scale, even if only partly implemented, has clear consequences for farming in Britain. The world surpluses, apparent rather than real, which characterised the pre-war food position would be rapidly absorbed, and increased production rather than restriction would become the keynote. This would entirely change the international supply position, which was formerly one of the factors limiting the competitive efficiency of British farming. Already the first international organisation created by the United Nations—the Food and Agriculture Organisation (F.A.O.) has brought out a World Food Plan which would afford the means for some fifty nations to co-operate on concrete measures for bringing about a rise in living standards and prosperity to agriculture and in industry throughout the world. It is not hard to see that in time world-planning will entirely replace market competition. In the short-term period envisaged at Hot Springs, it seems necessary that British farming should continue a high level of production of direct human food, including cereals, although the gradual easing of the shipping position will mean that the war-time pattern of production need not be rigidly followed. At the same time the production of milk, meat, vegetables and fruit will need to be considerably expanded. As the agricultural production of the world comes to be regulated less by the fight against hunger than by geographical considerations, the balance will inevitably shift, so that in time the position may be reached in which the so-called "protective" foods form a much higher proportion of total production in Britain. The establishment of this condition immediately after the war, however, would mean a departure from the programme of international nutritional advance laid down at Hot Springs. The short-term period, in which arable production for human consumption will be important, seems likely to last for at least ten years. It is to the needs of this period that the policy here set out is primarily directed.

The General Pattern of British Farming. British agriculture must remain flexible, and it must aim to maintain a high level of soil-fertility. Its efficiency in terms of human labour and in output per acre, high as they are, must be raised so that the necessary increases can be brought about simultaneously with an increase in rural standards of living. The present system of marketing, which increases prices roughly two and a half times between the producer and the consumer, must be replaced by something less cumbrous and wasteful. These general measures should make possible an agriculture which combines high farm-wages and rural prosperity with cheap and plentiful food in the towns.

The Increase of Agricultural Production. The general pattern of farming which can meet these conditions is undoubtedly ley-farming. This involves ploughing-up most of the permanent grassland, while new leys of grasses and clovers are laid down, in rotation, over the whole of the arable land. Both arable and grassland types of production are thus maintained almost everywhere, the balance between them being determined by geography and the needs of national policy, expressed through the direct planning of cropping or, ultimately, by price control. Both types of farming benefit by the association: the feeding value of the leys is greater than that of most permanent pasture, and the fertility of the soil is increased. The two main technical problems are the establishment and management of leys under the wide range of British conditions, especially in the drier areas, and the production of grass- and clover-seed. General studies of establishment, management systems, suitable rotations of crops in the arable break, effects on productivity and soil nutrient status, are all necessary. The expansion of seed production will require close control and should be associated with breeding work and certification.

Many problems of ley-farming still require investigation. There is need for work on the relations of different herbage species to each other and to the grazing animal, under different systems of management and on different soils. These ecological studies should be combined with studies of the environmental requirements and general physiology of particular species, and of their habits and mode of growth (morphology). The maintenance of productivity during dry periods, and the relations of grass and clover to nitrogen supply provide other series of problems to be attacked by the techniques of ecology. There is also need for an attack by small-scale and laboratory investigations on many of the problems of practice; these investigations have so far been few in number.

Livestock. The most important task of the livestock branch of the industry (in the past the principal branch) is the production of milk. Previously attention has been concentrated on the fattening of beef-stock with imported cattle-foods, a system in which the permanent pasture was often little more than an exercise ground, unused in the winter except for shooting and hunting. Even the few arable crops grown under these conditions were produced with half an eye on the requirements of game-birds. Certainly, as the national milk supply increases, there will be room for an expansion of meat production, but this should be carried out in a manner less wasteful of the potentialities of British soil than was formerly the case.

Many of the problems of milk-production are connected with performance recording. One of the most important of the necessary improvements is the perfectly practicable one of raising the yield of milk from the present average of 400 gallons per annum per cow, to about 800 gallons; many cows already reach 1,000 gallons. To maintain inferior animals is a waste of feeding-stuffs. Recording can also be a valuable guide to breeding. Here the increasing use of artificial insemination should help in rapid improvement of the national herd, if the genetic factors involved be scientifically assessed.

The animal public health service advocated by the President of the Veterinary Medical Association, combined with a survey of the actual incidence of disease (including sterility, morbidity from unspecified disease and nutritional deficiency) should be a powerful means of eradicating contagious abortion, mastitis, bovine tuberculosis, foot-and-mouth and other diseases, and of improving production. While these measures are improving the health of the herds, the safeguarding of human health and the prevention of wastage by inspection of dairies and the pasteurisation of milk are also essential. A very important problem is that of clean milk-production and clean distribution. Clean production is often made difficult by the bad design of cow houses, but mechanical milking and educational or supervisory measures could do much to improve matters. A strong case could be made out for the centralised supervision of all milk supplies by local authorities; contaminated milk is too dangerous a poison to be allowed to reach the public.

Machinery. The increased and better use of machinery is undoubtedly the principal means by which farming efficiency can be increased. The object should be to remove the tremendous burden of sheer labour which still characterises farm work; the day of cheap and abundant hand-labour is long past. Not only is wider and better use of existing machines needed, but also the development of new types suited to British conditions. Improvements in the technique of manufacture, such as the abandonment of the use of cast-iron, which results in so much breakdown and delay, are urgently needed.

Machines are wanted for loading, for handling of bulky materials (e.g. farm-yard manure) and for many operations, like weeding in horticultural crops, which at present take much hand-labour. There are many tasks, especially in horticulture, which will probably always require some hand-labour because they involve a high level of selection or discrimination by the human mind; but it should be an objective of agricultural engineering to mechanise all those operations or parts of operations which involve mainly human muscular power. Important savings of labour and an increase of productivity are to be looked for through the chemical control of weeds.

The question of eliminating unnecessary hand-labour carries with it problems of the supply of electrical power to farm buildings and houses, and the creation of a body of skilled agricultural mechanics. It involves a change and an increase in skill, and hence in the pay, of agricultural workers, and the provision of the amenities, transport and other services which the rural population will increasingly require. Investigations will be needed on the modification of traditional practices, and the design and lay-out of farms and buildings, in order that machines may be more widely and effectively used. The problems of farm buildings centre on the present nearly derelict state of many of them. It is doubtful whether the extensive capital outlay involved in their reconstruction and in the technical re-equipment of the land (drainage is the main expense) can be carried out without State support and intervention extending even to the national ownership of the land. In any case, close studies of design and lay-out of buildings in relation to roads, power supplies and convenience in loading and drainage are required.

Soil Fertility. The essential problem, on which any programme of economic expansion must depend, is the maintenance of fertility over long periods under intensive cropping. Over great areas of Britain, in spite of the headway made during the war, shortages of lime and phosphates limit production; especially is this true of the highly organic soils of old grasslands in the wetter areas. One of the first post-war tasks should be to complete the reconditioning of all land which is in this condition, particularly the so-called "marginal" lands where they are not of such low inherent value owing to bad drainage and siting that they are of value only for forestry. Even if some marginal lands are to revert merely to rough grazings, their value would be much increased by ploughing, reconditioning and re-seeding, where local conditions make this physically possible. In the specialised field of fruit and vegetable growing (horticulture) it seems likely that potash shortage is one of the main soil problems.

The British soil survey should be completed, even if it is not certain whether it is essential in order to achieve a high level of fertility. This fundamental work on the origin, development and distribution of the different types of soil would enable many soil problems to be defined with greater clarity. Inherent differences between soils in fertility and in response to the application of fertilisers could be linked with the characterisation of soil-types. Studies of the minerals present in different soils would provide information on the compounds of phosphorus, potassium and other important elements present; this might lead to a better understanding of the complex problems of nutrient availability. The methods of soil-analysis used by the Advisory Service should be standardised and calibrated by means of an extensive series of field-experiments covering all crops and soil-types. Soil-testing by rapid methods should be more widely used in order to show extreme conditions of acidity and of calcium, potash and phosphate shortage. The present arrangements for routine analysis should be expanded to deal with at least two million soil samples annually; it is doubtful whether the number at present exceeds half a million annually. These measures would make soil studies the basis for more accurate and useful advice to farmers than is at present possible. They would help in the continuous control of changes in fertility with cropping and enable more intelligent and economical use of manures and fertilisers to be made. Field experimentation should provide information on the physiological requirements of crops which could lead to the further development of a rational and economical fertiliser policy. Especially in the case of vegetables and fruit, very little accurate information exists, and there is here much investigation to be done. Much light will be thrown on these questions by the continuance of the survey of fertiliser practice which has already been begun.

"Trace" elements are so called because they are needed by plants only in minute amounts (traces) as compared with the large quantities necessary in the case of nitrogen, phosphorus and potassium. Boron and manganese are the trace elements most commonly lacking under British conditions. Studies on the role of the trace elements should be extended to the detection of hidden deficiencies, which may produce lowered yields of crop without obvious external symptoms of plant or animal disease. It seems likely that the present high concentration of workers in this field is excessive in relation to the small number of workers engaged in other more important fields. The latter should be increased to restore a better balance.

It is generally agreed to-day that, in addition to the nutrient elements supplied in fertilisers, additions of organic matter to the soil are important in order to maintain or to develop good soil-structure, water-holding capacity and aeration. The provision of organic matter for general farming is likely to come mainly from the ploughing-in of leys and from their associated animals. For horticulture, where organic matter is more important, it seems likely that new methods must be sought, such as the combination of leys and extensive stock-raising with the production of market-crops. The most efficient ways of using in rotations the supplies of organic matter which are available also need to be determined. The development of all these studies means increased research in plant-physiology and plant-biochemistry, both of which are backward in Britain in comparison with the corresponding animal studies. This research could further lead to an objective study of the factors controlling the quality and nutritional value of foods. These factors may be related to specific physiological states, such as immaturity, of the crop. Thus in the case of cabbages the objective of the grower is to produce a high yield of buds (for that is what a cabbage is) while the plants are still young, or physiologically immature; with other crops, especially those supplying carbohydrates, rapid maturing is important.

Plant Breeding. For most agricultural crops the breeding of suitable varieties is well developed, but much needs to be done for horticulture. Even where new varieties have been shown to be superior, they fail to be generally used because of the lack of suitable organisational measures. Problems such as the production of varieties best suited to the short British growing season for many crops, must be tackled. Vernalisation might help here, especially when the physiological significance of the process becomes better understood; but in the long run breeding will probably provide the better solution.

The general methods for the production of new varieties are now well known. However, further studies of the production of polyploids by the use of the alkaloid colchicine would be valuable. Polyploids are varieties in which the number of sets of chromosomes in the individual cells has been increased; such plants are usually larger than those whose cells contain the normal number of sets of chromosomes, and give correspondingly higher yields. Colchicine has the property of stimulating the production of polyploid offspring from normal parent plants.

The principal problems in the use of better seeds and varieties of plants are those of organisation. There is need for a great extension in the testing of varieties on a regional basis, and the popularisation of good ones, as in Sweden. Investigations of the nutritional requirements of different varieties and of their food-values could be carried on simultaneously. The certification of stocks (especially necessary in the case of fruit) could lead to the encouragement of the development and use of improved varieties.

Plant Diseases. The most serious diseases of crops in Britain are probably those caused by the potato-eelworm and the sugar-beet—*brassica* eelworm. Work on these is hampered by insufficient fundamental work on their physiology and ecology; too few scientists are engaged on this problem. Similar remarks apply to wireworm studies, especially in relation to duration of leys in ley-farming. In grassland, wireworm populations increase, and it is important to find out at what age the number of wireworms in a ley is likely to become sufficiently great to damage a subsequent crop.

Plant viruses, particularly those of potatoes, are perhaps next in importance as a source of damage. A considerable amount of field and laboratory work has been done, but control measures other than the production of virus-free seed are not yet in sight. The insect parasites of crops, especially of vegetables and fruit, present another group of problems in which ecological studies and work on insect biochemistry and physiology will have to be developed. The most effective use of the newer insecticides needs to be worked out.

There are several plant diseases which still cause great losses although control measures are known. The most important of these are potato blight, fruit diseases and leaf-stripe of oats. Like many other plant diseases, however, control here is partly dependent on the development and wider use of spraying and dusting machinery. So far as it exists such equipment is at present largely in the hands of private contractors whose work, although effective, is hampered by the large areas to be covered and the consequent excessive travelling times. Such services should be operated more widely by county authorities. Control measures should be planned on the basis of continuous field studies of the development of attacks.

The Encouragement of Fundamental Research. In general there is need for more fundamental work in agricultural science and general biology, particularly in ecology, physiology and biochemistry. To provide sufficient numbers of workers trained in these fields encouragement must be given to their studies by the universities. The approach to agricultural science outlined above can, in fact, become an important stimulant to a great development of biological studies in Britain.

There are numbers of specialised fields not mentioned above where the need for a special research station is strongly advocated; e.g. research on a husbandry basis, as in the vegetable-growing industry. Nor have important problems connected with soil texture and drainage been dealt with.

But this is a reflection of the present low level of soil physics studies in Britain rather than of failure to appreciate the problems; it has not been possible to secure an adequate and authoritative survey of this field. The problems of heavy-soil cultivation, and the design of suitable machinery therefor, are of great economic importance in the Midlands and East Anglia; and there are also special problems of fen-farming.

The agricultural advisory and educational services are mentioned elsewhere (p. 169). It is necessary here to stress the need for these services to be adequately staffed with qualified workers. The separation between the National advisory service and the County educational service, which has been proposed, threatens to produce serious problems unless means of co-ordination and co-operation are found.

Economics. Limitation of space forbids the discussion of the many problems of agricultural economics. The relative economic efficiency of holdings of various sizes used for different types of production in different parts of the country is the problem most in need of investigation. The objective should be to determine for each locality the most efficient methods of using capital and land. No general solution for Britain as a whole can apply, and a considerable amount of local and regional investigation will be needed.

7

TWO INDUSTRIES OF THE FUTURE

PLASTICS AND FERMENTATIONS

THESE two industries have been selected for consideration because, more than any others, they represent technical innovations, and at present their scale of production in Britain is small. In both industries considerable research work is still required before their potentialities can be fully exploited, but there is no doubt that they will play an increasingly important part in the national economy.

PLASTICS

What are Plastics? Plastics are manufactured substances which can be moulded, rolled, drawn or pressed into shape when moderately heated; they are raw materials of a new type.* The older raw materials, like wood, metals, stone, bone, ceramics, leather, wool, cotton, flax and rubber are found in nature and are only slightly, if at all, modified before they are used. Plastics are complex carbon compounds, built up (i.e. synthesised) from simpler substances by chemical methods. They are made from a wide range of materials by complex and rather lengthy chemical processes, which thereby build up entirely new substances with new and valuable properties. Moreover, by virtue of the flexibility and power of organic chemistry a wide range of plastics may be produced, each with its own characteristic physical and chemical properties.

The older raw materials are used very much as they are obtained in nature, and their natural properties limit the use that can be made of them. When a new type of article was required, that raw material had to be chosen which gave the closest approximations of properties to those required; very often the approximation was very rough indeed. The widespread use of glass, for example, where a transparent fairly strong material is required, carries with it the acceptance of its brittleness, its density and its high coefficient of expansion, so that glass articles break easily, are heavy, and cannot stand sudden changes in temperature.

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* *Plastics.* This chapter does not attempt to cover all the technical aspects of production of plastics. For further details on this subject see *Plastics*, by Yarsley and Couzens (Penguin Books, 1942).

The development of plastics makes it possible for the first time to design raw materials specially suitable for a given purpose. Already a wide range of materials is available, but theoretically the range is wider still. As the physical and chemical forces which hold the molecules of solids together become more clearly understood, so also will the relationship between the chemical constitution of a solid and its physical properties. On the basis of this fundamental knowledge new plastics will be designed which will incorporate most, if not all, of the properties required for a given purpose with as few undesirable ones as possible. The characters of the raw materials to be used for many purposes are thus more closely under human control than ever before. Materials can be used more efficiently and more sparingly; their qualities can be both more uniform and more controllable. Indeed, the control over material which the design and manufacture of plastics gives is the main significance at the present time of this new class of artificial product.

The social importance of plastics lies not only in their adaptability to existing needs. In many fields of industry they make processes possible and provide raw materials for articles and components that formerly could not be made at all for lack of suitable materials.

Ease of working is another great advantage of plastics. Many articles can be made directly by moulding plastics at moderate temperatures. The production of moulds and dies for this work is expensive, but the process is suited to production of large numbers of similar objects. Even when plastics have to be machined or worked-up to their final form this process is often simpler and cheaper than with metal, wood, stone, ceramics or glass. In brief, then, the important properties of plastics are fitness for purpose and ease of working. They have a great part to play in the mass-production of many sorts of articles needed in great quantities, as well as in the manufacture of machine-parts, electrical gear, and other industrial needs.

The range of articles already made from plastics is very wide. Synthetic textile fibres (e.g. nylon) have already secured a firm hold because of their excellent properties, and have a beauty of their own. Telephones and fountain pens and many other articles are universally made of plastics to-day. The war caused a great expansion of the industry. Plastics have been used for aeroplane turrets, the fusecaps of shells and for hundreds of other essential components. The methods of handling plastics have been greatly developed; large and complicated mouldings are now possible and resistance and toughness have increased as new types of plastics have developed. In the future plastics will certainly be used for automobile and aeroplane bodies, doors, windows and furniture, and for a multitude of household articles.

The clothing and footwear needs of the world exceed the present capacity of the natural textile and leather industries. Artificial textiles, leathers and rubbers will be needed to supply the known world requirements. However, there is no question of plastics completely replacing natural materials in all the above-mentioned fields. Steel, wood, stone, non-ferrous metals, etc., all have their places for their own highly developed purposes.

Britain and the Plastics Industry. Beginning with cellulose nitrate, first used as a plastic in Britain ninety years ago, the production of cellulose plastics, including fibres (e.g.

"artificial silk") has developed into an important British industry. But for other types of plastics as a whole, British production lagged seriously behind that of other countries; e.g. in 1937, production at 28,000 tons was only 42 per cent of German output and less than 30 per cent of the U.S.A. output. War-time increases of production in Britain have been small compared with the six-fold jump to 630,000 tons in 1943 in the U.S.A. It is frequently argued that the rapid advances in the U.S.A. or the Soviet Union are due to their favourable position with regard to raw materials, especially petroleum, and that British production thus is inevitably restricted. In fact, the size of the British industry at present by no means reflects the raw materials available or the potentialities of the chemical industry.

The central problem about the future of plastics in Britain concerns the scale of production; the production of 100,000 tons per year would probably involve no problems of raw material supplies and few of planning. But the production of a half to one million tons per year (not an exaggerated aim in view of the potential scale of requirements) would involve serious problems in the supply of raw materials. The basic future policy of this important industry should be to produce at low cost large quantities of urgently needed articles such as domestic equipment, prefabricated plumbing, textiles and components for the transport services.

Raw Materials for Plastics. The major basic raw materials from which synthetic plastics are made are coal, alcohol and petroleum hydrocarbons. The industry in Britain should be based on a balanced use of all three, with the emphasis necessarily on coal. The future of British plastics is therefore directly related to the efficient working of the coal industry. It also depends on the national planning of coal-consumption, and the maximum recovery of existing and potential by-products. This does not mean that petroleum-refining has no part to play in the development of British plastics. In the U.S.A. the emphasis is shifting towards the use of petroleum hydrocarbons, not only for synthetic rubber, but also for the synthesis of benzene hydrocarbons and phenols; 75 per cent of the phenolic material now used in the U.S.A. is made from petroleum. But even with the removal of the duty on the petroleum hydrocarbons used for chemical or plastics purposes, the development of plastics would be slow and one-sided; cheap coal is the main requirement in order to have cheap plastics. Table 5 shows the raw materials required for various plastics and indicates also how the entire resources of a developed chemical industry are involved.

TABLE 5

Type of Plastic	*Main Raw Materials Required*
A. Thermoplastic Resins (which can be softened on re-heating):	
Cellulose resins (nitrate, acetate, acetate-butyrate, ethyl cellulose)	Cellulose (wood, straw, cotton-linters, etc.), coal, sulphuric acid, nitric acid, acetic acid and acetic anhydride, butyric acid, soda, chlorine, alcohol.
Vinyl resins (acetate, chloride, alcohol, vinyl-vinylidene co-polymers, acrylic resins)	Acetylene (from coal *via* carbide or methane), acetic acid, hydrochloric acid, sulphuric acid, acetone (from molasses fermentation).
Styrene resins (polystyrene and styrene-butadiene co-polymer)	Benzene (from coal or petroleum) ethylene, butadiene (from petroleum gases, acetylene or alcohol)
Polythene and Polyisobutene resins	Ethylene (from alcohol, coke-oven gas or petroleum cracking)
Polyamide resins (e.g. Nylon)	Isobutanol, phenol (from benzene or, coal-tar), ammonia, nitric acid.
Coumarone-indene and β-pinene resins	Coal-tar, turpentine, sulphuric acid.

TABLE 5 (*continued*)

Type of Plastic	*Main Raw Materials Required*
B. Thermosetting Resins (which cannot be softened by re-heating):	
Phenol-formaldehyde resins (including cresol and substituted phenol resins)	Phenols (from coal-tar or by synthesis from benzene) formaldehyde (from coal *via* methanol or possibly methane)
Urea-formaldehyde resins (including melamine resins)	Urea (from ammonia and carbon dioxide or from carbide), melamine (from urea or from carbide), formaldehyde
Alkyd resins	Phthalic acid (from coal-tar naphthalene), maleic acid (from naphthalene or benzene), glycerol from vegetable oils or synthesis.

To the materials listed in Table 5 must be added many solvents and plasticisers, into the cost of which the price of coal enters as the largest single factor.

Basic Requirements for the Development of the Plastics Industry in Britain. It is now possible to set down briefly the main needs for the development of plastics production in Britain:

(*a*) *Coal.* It is essential that very definite steps be taken in the future to make the fullest use of the by-products of coal. The recovery of benzol and tar acids should be made compulsory; this would increase the supplies of benzene and phenol, both of outstanding importance. Attention should also be paid to a revision of the present primitive methods of domestic heating so as to permit the recovery of a large part of the values destroyed in the consumption of 40,000,000 tons of coal per year. Further quantities of benzene could be obtained by the chemical treatment of coal (hydrogenation) and petroleum. By these various means it would be possible to increase benzene production to more than half a million tons per year, allowing the production of polystyrene, phenolic, alkyd and polyamide resins at the 100,000 tons per year level. Thus the greater portion of these amounts could be obtained by the national planning of coal-utilisation.

The production of vinyl resins starts with acetylene which can be obtained from the ultimate raw material, coal, by two processes: (*i*) from calcium carbide, a method requiring a high consumption of power; (*ii*) from methane, obtained by coal carbonisation. Because the present modes of electric power production mainly use coal, a wide development of process (*ii*) seems advisable. Nevertheless it is of interest that the production of calcium cyanamide *via* carbide, if on a sufficiently large scale, is not more expensive under British conditions than are other methods of fixing atmospheric nitrogen, and it is probable that the production from carbide of acetylene or cyanamide and melamine resins could be economic. However, the present conditions favour methane recovery from all sources (carbonisation, blow-holes and sewage) as the starting material for vinyl resin production up to approximately 200,000 tons per year; further developments could arise if more hydro-electric power were available.

(*b*) *Ethanol* (*alcohol*). A national policy of industrial ethanol production is long overdue, since it is an important raw-material for fuels, solvents, heavy and fine organic chemicals as well as plastics and artificial rubber. The use of 0.5–1 million tons per year of ethanol can be envisaged. This would require the fullest use of all available sources of supply, namely: (*i*) the duty-free importation, for industrial purposes, of ethanol from molasses-fermentation in the colonies, in order to save transport costs and shipping-space; (*ii*) production in Britain from agricultural (cellulose) waste and directly grown crops (e.g. potatoes); (*iii*) production of ethylene by cracking refinery gases, and the recovery of ethylene from coke-oven gas, in order to manufacture ethanol by hydration. These measures would permit the development of acrylic, butadiene, polythene, and other plastics to the level of 100,000 tons per year.

(*c*) *Petroleum.* Where substantial petroleum deposits exist large-scale chemical and plastics developments can and will arise on the site, using not only the refinery by-products but also the large amounts of accompanying natural gas (largely methane).

In Britain, reliance would have to be placed on imported crude petroleum as the starting material for synthesis. While the greater part of plastics production in Britain must come ultimately from coal and to a lesser extent from ethanol, there is a good case for the relaxation or removal of the hydrocarbon duty on petroleum materials to be used for chemical products and not for fuel, providing that fiscal policy be framed in relation to the needs of national planning and of Britain's responsibilities within the framework of United Nations planning. Backward countries possessing petroleum should be encouraged to process some of it, in order to export organic chemicals of higher value.

Conclusion. An eventual target of 1,000,000 tons per year of British plastics may seem ambitious when compared with the pre-war production of $\frac{1}{30}$ of this amount. State-directed expansion in the U.S.A., however, had resulted in production at the rate of 700,000 tons per year approximately by 1943, and the production of synthetic rubber in 1944–5 was at about the level of 1,000,000 tons per year. A substantial proportion of the latter production capacity could be diverted to the production of other plastics (e.g. polystyrene resin) if the use of natural rubber were resumed on the pre-1939 scale. The complete restoration of natural rubber to its pre-war dominance seems unlikely; in any case plastic materials are coming into large-scale uses of their own, replacing traditional materials for many purposes. It is clear that the development, production and use of plastics on the scale envisaged emphasise the need for a co-ordinated national policy for coal-utilisation and fuel and power supply, to provide the raw materials.

FERMENTATION INDUSTRIES

The modern fermentation industry, which uses the products of the growth of yeasts, fungi (moulds) and bacteria, has grown out of the age-old craft of brewing, whose origin lies far back in unrecorded history. Brewing developed independently in many centres from casual observations on liquors of various kinds which had been fermented by chance inoculation with micro-organisms which were present naturally. With the development of a scientific study of the fermentations and other processes caused by micro-organisms, the organisms which were responsible became known. It is now possible to select species of micro-organisms which will carry out very many syntheses or chemical changes which are difficult, very expensive, or at present impossible to carry out by chemical means.

Brewing is still, in size, the most important part of the industry; subsidiary to it is the yeast industry. These will not be considered here, but only some of the more recent developments which indicate future possibilities. Among the more recent developments have been the manufacture of citric acid and other organic compounds by fermentation methods, and the large-scale production of anti-bacterial and other antibiotic substances (antiseptics) for medical and other uses. Penicillin is the most popularly known example of this kind of natural antiseptic. At present the potentialities of the use of micro-organisms for the manufacture of valuable chemical products are only exploited to a very limited extent.

Fermentation products may be divided into two categories: (*i*) raw materials for other branches of industry, e.g. industrial ethanol, butanol (for synthetic rubber), acetone, citric and gluconic acids (for the food industry and pharmaceutical use); (*ii*) fine chemical products, made more easily by fermentation methods than by organic chemical synthesis, and those whose chemical structures and methods of synthesis are not yet known, e.g. natural anti-bacterial substances such as penicillin. The scale and variety of operations in the fermentation industry in Britain is very meagre in contrast to developments in other countries, notably the U.S.A.

The primary needs for a successful fermentation industry are cheap sources of raw materials, of which an important part is some inexpensive carbohydrate: sugar, starch or cellulose. Useful carbohydrate may be present in waste or by-products from other industries, especially agriculture. The difficulty of providing cheap raw materials might be the chief obstacle to the development of fermentation processes in Britain. While the world food situation remains acute the importation of raw materials for fermentation processes may be impossible; that is all the more reason why the utilisation of agricultural and other waste products should be investigated. The most obvious source of carbohydrate is cellulose, abundant in wood and vegetation. The Bergius process for hydrolysing cellulose by hydrochloric acid may make possible the conversion of waste wood and vegetation into forms usable by micro-organisms.

Whatever the immediate prospects for developing a large-scale multi-product fermentation industry in Britain, it is clear that the potentialities of the industry are so great that means should be adopted to provide the prerequisites of knowledge and trained workers so that every use can be made of the extreme versatility of micro-organisms. At present Britain lags far behind the best levels of technique; and there is an acute shortage of trained workers for the rapidly expanding antibiotics industry (pencillin, etc.). Moreover, while Britain remains the centre of gravity of scientific research within the British Empire, it is imperative that microbiological research be fostered here, since even if the raw materials for a large-scale fermentation industry may not be available in Britain, the contrary is the case with large areas of the Empire overseas. Tropical vegetation may provide a superabundance of raw materials that can be most economically worked up by microbiological methods.

There are a number of causes for the backwardness of British microbiology. The development of fundamental research in microbiology has suffered from the lack of co-ordination of the different specialist fields and from the very unbalanced emphasis which has been placed on a few of these. There are historical reasons for this. Specialist studies of the micro-organisms associated with human and animal disease (medical and veterinary bacteriology) and with special industries (brewing, food control, agriculture, sewage disposal, etc.) have often been intensive; but there has always been a lack of teaching departments, capable of co-ordinating and developing the training of all-round microbiologists, and of facilitating balanced programmes of fundamental research in microbiology as a whole. The time is now ripe for a reorganisation and integration of the various relevant branches of biological science so that general microbiology may emerge as a fully-formed science and develop its full potentialities. For this to be possible steps should be taken to organise teaching and research departments of general microbiology. Without this, the various streams of biological science which make up modern microbiology will not unite fruitfully and the old and stultifying narrow departmentalisation will continue. The recent founding of the Society for General Microbiology gives a good indication of what microbiologists themselves feel about the need for co-ordination and co-operation. To enable the science to develop as it ought, both because of the importance of its fundamental contributions to biology, and of its applications in production and medicine, properly organised teaching and research departments at the universities are essential.

One other important factor which has retarded the development of microbiology in Britain is that the large store of knowledge and experience which is in the possession of private firms operating in the fermentation industry has been guarded very closely. The publication policy of these firms has, on the whole, been very restrictive. Private firms in other industries have found that, in the long run, nothing but benefit comes from a liberal publication policy, because this fosters the development of fundamental science which is the life-blood of industrial development and application. Publication policy by private firms in the U.S.A. is much more liberal than in Britain, and private enterprise in the U.S.A. shows in many fields much higher levels of technical development. A continued policy of secrecy in Britain will only hamper development in the long run.

8

HEALTH AND THE MEDICAL SERVICES

IN this field the ground is prepared for greater progress than in any of those surveyed in this book. A measure is already on the Statute Book which will profoundly affect the form of the medical services of Britain, and an important and careful report prepared by the inter-departmental Committee on Medical Schools (the Goodenough Report) has discussed the provision and education of the doctors who will staff these services and of the people who will do research in this field. The proposals below must be read in relation to the National Health Service which will come into operation in 1948, and to the Goodenough Report.

The National Health Service. General approval and support must be given to the proposed National Health Service, whose main outlines follow those already approved under the late National Government. Many details upon which its successful working will depend remain to be filled in, but the provision of a comprehensive centrally financed service cannot fail to emphasise the need for measures to *prevent* ill-health. Such preventive measures have not been evolved by those responsible for these services in their present fragmentary condition. This is partly because adequate preventive measures can only be successfully operated on a national scale. The National Medical Service can be distributed according to need rather than the capacity of any particular area to pay for its requirements. A national health budget will also cause a closer inquiry into the effect of housing conditions, feeding, etc., on human health, i.e. into factors outside the limited medical ambit. The proposal to establish adequately equipped Health Centres which will provide better facilities for the practice of scientific medicine is to be warmly welcomed. If supplied with adequate secretarial staffs, these Health Centres will provide the possibility of collecting invaluable data for research. Reliable information about morbidity trends, for example, could be collected; this could indicate those fields in which inquiry is most urgently needed. Collective practice in the Health Centres and the abolition of the sale of private practices should enable doctors to regard each other as colleagues rather than as competitors, and should "remove the profession of medicine from the atmosphere of the market-place." There is, however, some danger that if practitioners employed in the National Service are also allowed to practise privately, the public may suppose that the service provided by practitioners in their private capacity has some advantage over that provided by the State. It is essential that any suggestion of inadequate facilities or attention, which was associated with "panel practice" under the National Health Insurance, should not be carried over into the new service which is designed to serve the whole community. Members of the medical profession will be more respected and, in reality, more free to devote themselves to the science and art of medicine if they become salaried servants of the community.

Industrial Medical Service. It is unfortunate that the provision of a national industrial medical service has been excluded from the scope of the National Health Service and that the provision of doctors in industry is left to private enterprise. As a result of the Factories (Medical and Welfare Services) Order, 1940, there has been a considerable influx of doctors into industry during the war, but medical supervision is still confined to the larger units and is rudimentary in transport undertakings, offices, hostels, shops and on building sites. The latest available figures (for 1943) showed that these were only 176 whole-time and 750 part-time works doctors serving probably less than 25 per cent of the industrial population and, apart from the Royal Ordnance Factories, there is no semblance of a coherent industrial medical service. The Association of Industrial Welfare Officers have themselves asked for a complete service, which should clearly cover the very large number of small factories as well as the larger units, and should be extended to the other types of employment mentioned above. The central Ministry responsible for the National Medical Service must eventually also be responsible to Parliament for this industrial service, although direct control might well be on a regional basis. The industrial medical services must be integrated at all levels with the general health service so that every worker is provided with medical supervision at his place of employment as well as elsewhere.

The industrial doctor is too often thought of as a casualty officer whose place is in the factory surgery. In progressive medical departments, however, while providing emergency treatment, the staff consider their principal responsibility to be the prevention of injuries and ill-health by the control of general factory environment, in addition to the control of special hazards. They also wish to promote physical and mental fitness by the improvement of working conditions and by attention to personal health needs. Rehabilitation has been included as part of the National Health Service and the Disabled Persons (Employment) Act of 1944 makes provision for resettlement in industry of persons who are incapable for medical reasons of following their previous employment. Rehabilitation applies not only to injuries but also to illnesses such as neurosis and tuberculosis. An industrial medical service closely linked to the rest of the medical service will be essential for the care of workers returning after illness or injury.

At present in private industry doctors and nurses are employed by, and can be discharged by, the managements. This has tended to create an atmosphere of mistrust amongst the workers which is likely to increase during periods of redundancy. This is resented by the doctors themselves, most of whom wish to do a thorough job free from any suggestion of divided loyalties. The industrial medical service should be financially independent.

The Trade Unions are becoming increasingly interested in health and welfare matters and could be of direct assistance to an industrial medical service. The shop stewards could co-operate with the works medical departments in such matters as ventilation, lighting and heating, canteens and incidence of illness, and could also assist in the health education of the workers they represent. Factory Health and Safety Committees are already developing and should be extended. The Factories Acts form an important background to industrial medicine but do not, at present, operate in transport undertakings, offices, shops or laboratories. As an industrial medical service develops, the Act should be extended to cover every worker or it should be replaced by a new Industrial Health and Welfare Act.

Britain has lagged behind other countries in industrial medical research, which needs to be developed to deal not only with specific hazards but also with the ordinary illnesses affecting workers. As examples may be mentioned: the prevention of colds; the problem of lighting in coal mines; the prevention of deafness in boiler-makers. The work of the Industrial Health Research Board should be expanded and the Central Bureau of Information, recently set up by the Factory Department of the Ministry of Labour to deal with inquiries on industrial health, needs to be better known and more widely used.*

The Future of the War Emergency Services. Special provision has been made in the National Health Services Bill for the Ministry of Health to continue the work of the Emergency Public Health Laboratories and the Emergency Medical Service Laboratories. These organisations grew up during the war and have provided an extremely valuable service for medical practitioners throughout the country. For the first time they have had available readily accessible laboratories to which specimens could be sent for examination and report, without the delays involved in using the postal services; and pathologists have been available for consultation on individual cases and on general epidemiological questions. Their continuance and development is especially welcome, since they provide the basis for specialised laboratories to which difficult problems of epidemiology can be referred.

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* For fuller information see the *Memorandum on the Industrial Medical Services*, issued by the Association of Scientific Workers.

The Training of Medical Laboratory Technicians. It is obvious that the growth of the pathological laboratory service will raise problems not only of accommodation but also of the recruitment and training of adequate staff; many qualified pathologists and technicians will be required. If the best qualified people are to be attracted to this service it is essential that there should be a clear indication of the scale of development contemplated, the conditions of service and the provisions to be made for training the greatly increased number of skilled technicians that will be required. There will be a large number of service-trained technicians released from the Services. From these it may be possible to meet the immediate requirements of Health Centres, hospitals and the public health laboratory service, but there will not be sufficient of the category of technicians required in the universities and medical schools. In envisaging the requirements of the latter institutions and the future needs of hospital and public health laboratories, both the type of training required and the recruiting difficulties due to competition with industry must be considered. The training at present available for laboratory technicians is largely unorganised and very variable in scope. Some employing bodies have arrangements with local technical institutes, others advance money in selected cases and to a limited extent the technicians organise and conduct their own classes, but generally speaking schemes of continued education and training are non-existent. The Association of Scientific Workers has circulated a memorandum on the education of technicians.* Steps should be taken, in co-operation with the other interested bodies, to implement the scheme for training as rapidly as possible.

The Medical Staffs of Hospitals. The National Health Services Bill has tackled the problem of the voluntary hospitals boldly by proposing that the Minister of Health take them over entirely. Despite their traditional position, which financial considerations were making increasingly difficult to maintain, their separate existence would have been a great obstacle in the way of a unified hospital service, and this step has the approval of the great majority of people. The autonomous position of teaching hospitals has however been safeguarded by granting them a separate administration to give latitude for clinical teaching, experiment and innovation. There is nevertheless some danger that if they were to remain staffed by part-time consultants, as at present, they could be used to provide beds for private patients to the detriment of the Health Service as a whole. It is important that the teaching staffs should be whole-time in the Service, and drawn partly from the hospitals associated with the main teaching hospital, as proposed by the Interdepartmental Committee on Medical Schools. Both for this reason and because of the admitted need for improving the training of enough doctors to supply the Health Service, action upon this Committee's report should be taken soon.

Medical Research. The active prosecution of research and the provision of adequate facilities for it is an essential part of any national medical service which aims not only at caring for the sick but at preventing disease. It is essential that the closest contact be maintained with advances in veterinary and agricultural research, since there is no sharp dividing line between the diseases of man and of other animals; and agricultural research should have a definite relation to the nutrition of the community. Advances in chemotherapy indicate the need for similar close contact with manufacturing chemists. There should also be contact with other workers, e.g. physicists and radio-engineers working on apparatus and instruments, since the medically-qualified research worker is often ignorant of technical details which would assist him.

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* See *The Training of Medical Laboratory Technicians* (A.Sc.W., 15 Half Moon Street, London, W.1.).

It has not hitherto been recognised that it should be the function of an official body to survey the health of the community and to initiate research on problems so revealed. Although under the new Act the Ministry of Health will have wide powers to conduct research, the Medical Research Council by virtue of its experience and prestige is probably best fitted to undertake this task. If it does so it will need a considerable increase in its funds to fulfil such duties. The Goodenough Report in discussing the Medical Research Council states that "Grants are made on the basis of applications. The initiative thus comes from the individual worker or his chief, and the Council's decision to give help depends on the suitability of the worker and the choice of subject." This system works well enough in promoting original work along new lines, but is inadequate for following up and applying promising observations. In addition to the co-ordination of research, the Council should accept responsibility for: (1) The collection of information on the health of the country from vital statistics and other sources, and the use of this information to indicate fields of research awaiting development; (2) The initiation of research arising from problems in the practice of medicine; (3) The publicising and application of knowledge gained by research. The recognition that these functions should be part of the responsibility of the Medical Research Council would call for the creation of surveying and Planning sub-committees of the Council, which could fulfil the sort of functions that the Agricultural Improvement Council is designed to perform in relation to agricultural research.

Medicine is no exception to the other fields of thought and activity in which there is recognition of the need to encourage and assist those who have a flair for research. The problems of health and disease that cry for solution are innumerable. The Goodenough Report points out that "A community that wishes to promote research must do two things. First and foremost, it must find and train the men who have the ability and impulse for scientific inquiry. Second, it must create the most favourable conditions for their work and give them the tools they need." A third condition should be added: those responsible for framing the community's policy in this sphere must decide which problems are most pressing and in what directions research is likely to be most profitable. The necessary steps must then be taken to see that these problems are attacked by suitable workers with adequate resources. This, of course, does not mean that work on other problems should be discouraged, or that research workers should be dragooned into working on problems in which they are not naturally interested. There are many problems of academic importance which do not show immediate prospect of yielding results of fundamental significance or of directly benefiting the health of the community. Workers interested in these problems should be encouraged to continue their investigations and be given all the necessary facilities for their work. It is, however, vitally important that the available resources should be mobilised to bring the maximum possible benefit to the health of the community, and that the broad lines of policy should be appreciated by the public (see Chapter 13).

It is clear there will have to be a great increase in the provision from public funds of money for medical research. It is estimated that the National Health Service will cost about £152,000,000 per annum. Of this sum, £5–7,000,000 would not be an excessive allocation to aim at for research, as workers become available, in view of the dividend in improved health and all the social and economic values that might be expected to follow. In 1938–1939, the Parliamentary grant-in-aid to the Medical Research Council was £195,000, which rose to £250,000 in 1944–45. This gives some measure of the increased scale of financial provision that is required. Of the money provided for medical research, the major part should be allotted to the universities and allied bodies and the smaller part to the Medical Research Council, although the latter should be the main co-ordinating body. Since a great increase in the total sum provided is envisaged, it follows that the Medical Research Council would receive a sum much larger than any hitherto available and would be able greatly to expand its activities and to assume the wider responsibilities suggested above.

At present about £2,000,000 per annum is estimated to be spent on medical research in all types of institution. The spirit of collaboration between workers in related fields and in different laboratories is already much healthier than in other branches of scientific work. There is a tendency to look to the Medical Research Council for leadership and co-ordination; this has developed markedly during the war period. The framework for future expansion is thus already in existence, and could be affected with less organisational difficulty than in other branches of scientific work.

The general lines on which the more applied branches of medical research develop are likely to be conditioned by the national health budget. It is to be hoped that there will be less emphasis on rare disease conditions, of mainly academic interest, and more on the subjects related to widespread and at present often less well-understood causes of ill-health and incapacity for work or enjoyment. Such work should be directed towards topics such as: immunisation against childhood diseases; prevention and treatment of deafness; respiratory infections; rheumatic conditions; tuberculosis; menstrual disorders and sterility; peptic ulcers. Broadly conceived studies of the effect on health of food, domestic and working environment, and the study of senility, can also be expected to yield valuable results. These matters may be more decisive factors in obtaining positive health than is at present generally recognised. There is also much need to study the technical aspects of treatment and their background of fundamental science; skin grafting, physiotherapy and anæsthetics are examples of such topics.

Vocational psychology has been used with success in fitting the right men and women into the right jobs in the Services. In the post-war period, use must be made of all available man-power, and this science can have a valuable application to industry if tests are used for allocation, rather than for rejection of the less fit and less intelligent workers. Nevertheless future work in vocational psychology should aim at assessing the capacity of children so that they can be guided towards careers offering them the best opportunities, rather than aiming at selecting them for jobs in the interest of the employer's output only. Contrary to common belief, the use of psychological tests limits the part that personal prejudice and academic education may play in the selection of men and women for skilled jobs.

The Provision of Medically and Scientifically Trained Personnel for Health Work. The problem of providing an adequate supply of trained persons for the National Health Service can only be touched upon here, but until it is solved the service cannot become fully effective. Of primary importance is how to increase the number and quality of medical students. The results of questionnaires answered by doctors and medical students have shown that 86 per cent of their number is at present drawn from the wealthiest

20 per cent of the population. Scientists, on the other hand, are drawn from a much wider range of income-groups. The length and expense of the medical training have doubtless excluded many persons who would have made good doctors. The Goodenough Report stresses this problem and makes some recommendations, which, if interpreted generously, would go far to solving the problem.

The medical training syllabus is in a critical condition; at present it is required that new subjects be studied, while the old subjects continue to expand. Probably nothing short of a complete recasting of the medical training courses, regardless of the sectional outlooks of university departments, will permit of a well-balanced training of reasonable length and adequate for modern requirements. The Goodenough Report here states excellent general principles but fails to make specific proposals that do more than superficially modify the present situation. It seems that here the General Medical Council should realise its statutory responsibility and make use of its powers to attack a problem which the individual universities have allowed to become of formidable dimensions.

The training of specialists and research workers is a problem not sharply distinct from the general one of training scientific workers, discussed in Chapter 18. One specific proposal which may be made here is that courses should be initiated to acquaint the medical research worker with the fundamentals of clinical medicine at shorter length than in the present courses, whose length and detail is excessive for those not wishing to practise.

9

FOOD AND CONSUMER GOODS INDUSTRIES

THE FOOD INDUSTRY

THE improvement of the nation's health during the war may be attributed in the main to improvement in the diet of the lower-income groups, due to the elimination of unemployment, increased wage-rates and, above all, a food policy implemented through the rationing system in accord with the known principles of nutrition. Since nearly every other condition of life in Britain markedly deteriorated during the five war years, the conclusion that the quality and quantity of food is of fundamental importance in maintaining health is inescapable. There must be no return to the pre-war situation, the evil consequences of which have been described at length by workers such as Orr and M'Gonigle. The supply of food (determined by agriculture and import policy) must continue to be related to demand by a scientifically-based national food policy. Above all, unemployment and low wages, with consequent semi-starvation, must not be allowed to return. Scientific knowledge alone cannot achieve these results, but can only provide data to enable policies designed to provide adequate diets to be worked out: the policies themselves will depend on the political and economic background. There is, however, much scope for further progress in nutritional science:

(*a*) Ascertainment of the fundamental roles of particular dietary constituents. Our knowledge of the special role of particular chemical constituents of the diet under different circumstances is only at its beginning; progress requires the bringing together of data from a number of fields of study. The Nutrition Society is to be congratulated on its recent work in this direction. The implications of such work are often very important for agricultural practice, particularly stock-feeding.

(*b*) New sources of human food, such as food-yeast utilising waste molasses and other products, and protein directly extracted from green plants, require further investigation.

(*c*) The development of methods of cooking and preparing foods for large-scale catering in order to achieve the palatability attainable by the best chefs working on a small scale.

Food Technology. Certain problems concerned with the preservation, distribution and processing of food may be mentioned. The broad aim of food technology should be to ensure that food reaching the consumer is wholesome, palatable and of maximum nutritive value. Techniques of food processing worked out in the late 19th and early 20th centuries, such as refrigeration, canning and refining, arose from the need for methods of preservation and utilisation adaptable to the requirements of modern society. When efficiently applied they give food which is wholesome and palatable; but they were not consciously designed as methods which would also conserve the full nutritive value of food-stuffs. Indeed this was then impossible, as the essential basis of fundamental nutritional and biochemical knowledge was lacking. Thus, in so far as these methods did preserve nutritional quality, it was fortuitous rather than by conscious design. The perspective has now been transformed by the striking advances which have been and are being made in biochemical, biophysical and nutritional research, and by the possibilities made available by progress in physics and engineering. These developments would appear to open up fruitful avenues for post-war research in the food industry. The essential aim should be to modify and adapt the older techniques and to apply new ones in the light of the advances being made in fundamental biological knowledge. An example of such an approach under war-time control is provided by vegetable dehydration in Britain. Here nutritional quality in the final product was definitely laid down as a fundamental aim. Processing and engineering technique were then consciously adapted to meet this requirement. The future value of dehydration may lie largely in the ability to preserve excess food-stuffs not consumed at times of glut and to ease transportation problems so that varied diets can be supplied where climate, etc., makes mixed food production impossible. Parallel with this long-term type of investigation there is an immediate need for research and development work on the efficient application of existing methods, particularly the use of refrigeration in the meat, fish and vegetable industries. It should also be stressed that the maximum benefit from food research will only be obtained if it is closely integrated with agricultural research. These are some of the general considerations which should govern the orientation of post-war research in the food industry. Some examples of how and where they could be applied may now be briefly considered.

The fishing industry of Britain urgently requires the application of modern methods of food technology. At present gross waste goes hand in hand with indifferent methods. Studies are required of freezing both on the trawlers and ashore, the most suitable storage temperatures for different types of fish, and the use of modern methods of drying as a mode of preservation.

In the cereals industry, research should be directed to the problem of obtaining flour and other cereal products which retain the natural vitamins of the B group and minerals at a high level, without losing palatability and baking quality. A useful link could be made here with agricultural research through breeding and cultivating wheat and oats with a view to selection for high vitamin, low phytate and strong gluten content.

Great technical progress is possible in the home-grown meat industry. Slaughtering should be more centralised and refrigeration (not freezing) universally used; control and research laboratories should be associated with the centralised abattoirs. In this way methods could be worked out for the best utilisation of blood, endocrine glands and other by-products, which at present are largely wasted. Further, the application of refrigeration would mean improved hygiene—a step which is eminently desirable. There is scope in the bacon industry for intensive research on the curing process. Here again food research could most profitably be linked with agricultural research; pig-breeding research should be related to the established requirements of the curing factories.

Research for new methods in general food processing might well include the investigation of: radio-frequency waves for sterilisation and as a mode of drying; the application of vacuum freeze-drying to a wide range of biological materials; the direct extraction of protein and other nutrients from grass, lucerne, etc.; the fermentation of cellulosic waste material. Parallel with these investigations would go fundamental studies of the changes occurring *post mortem* in animal products, in products stored in various environments and in products preserved by refrigeration, canning and various modes of drying.

THE CONSUMER GOODS INDUSTRIES

Other industries which supply essential requirements for everyday life include: textiles and clothing; leather and footwear; glass and ceramics; furniture; rubber; hardware; laundries; paint; paper. Some of these industries are very closely related to the light engineering industry. They play a part in supplying the capital goods industries, but the major part of their product takes the form of consumption goods.

Raw materials for these industries are drawn from a wide range of natural products such as: cotton, linen, wool, hides and skins, timber, oils, fats, rubber, starches, gums, waxes and resins, various minerals, sands and clay. The development of modern chemistry has resulted in the possibility of replacing nearly every one of these natural products by synthetic or chemically processed materials, of which the various plastics are at present the most important group. There is scarcely an industry in this group which has not to reconsider from this angle the raw material which it ordinarily uses. It will be necessary in each industry to strike a balance between the use of natural and synthetic raw materials, in relation to the availability of each and to the quality of the product. It seems unlikely that the traditional bulk raw materials will disappear from use in these industries. Many of the natural raw materials are, weight for weight, cheaper than the synthetic materials can be in the near future. There is a big field for using natural and synthetic materials together in order to make articles with superior properties; plastic-impregnated cotton fabrics and aeroplanes made of resin-bonded plywood are examples of this. Special mention should be made of the need for materials to replace leather, since the world demand for leather is likely to exceed all possible supplies if the peoples of the undeveloped regions begin to demand leather footwear.

Very many accessory materials are supplied to the consumer goods industries by the fine chemicals industry, which also supplies drugs for medical and veterinary practice and materials for scientific research. A general criticism which may be made of the production methods in the fine chemical industry is that they are inefficient for much the same reasons as already mentioned in connection with the engineering industry, that is, a number of small undertakings operate similar small-scale processes, and cannot afford adequate research. Here the same type of scheme as proposed for the engineering industry would be helpful, namely a concentration of the production of particular materials in certain factories, with adequate protection of the purchasers against monopoly prices.

The fine chemicals industry and those who use its products would both benefit, since more attention could then be devoted to improving production methods.

At the present time the consumer goods industries need to be greatly expanded, for the destruction and wearing-out of household equipment has left an enormous deficit to be made up. What is wanted immediately are articles of good quality at a reasonable price and in adequate numbers. The standardisation of production on a few types of article of good design will in many cases be necessary in order to achieve this emergency level of production. Taking a longer view of the prospects of these industries, some desirable directions for development may be mentioned. The use of consumer research methods and the control of the quality of consumer goods sold should be developed in connection with the products of these industries (see Chapter 11). There seems no reason why, just as with drugs and food, the public should not be protected by law against the sale of inferior household articles, clothing and other goods, the poor quality of which may be no more obvious to the purchasers' inspection than is the presence of a deleterious preservative in an article of food. The establishment and enforcement of such standards is a desirable step for a wide range of goods. It would, for example, be useful to know the average life of an electric lamp or the shrinking property of a pair of socks at the time of purchase. Such standards should be *minimum* standards, and there would still be room for variety and differences of quality.

Most firms in the consumer goods industries are small. In many branches this situation may be expected to continue, since increasing the scale of production in many of the processes used does not greatly reduce the cost of the products. Such firms can well undertake their own research on the production of special articles and the improvement of their products. There are however some aspects of research and development which individual small firms cannot tackle; here there is scope for increased activity by the Research Associations which already exist in some of these industries. Three main directions may be suggested in which the Research Association could do valuable work:

(1) To undertake fundamental studies of the properties of the raw materials on which the industry depends, and to advise as to the applications of these studies in practice.

(2) In co-operation with the engineering industry, to undertake research into the improvement of the machines used in their industry. Very often a machine has become a standardised one, which does the job, but does not do it particularly well, and neither the manufacturer nor the user of it take any steps to improve it. This is particularly the case in the textile industry, where much machinery is quite obsolete; more automatic machinery is required here, to eliminate such distasteful and inefficient work such as loom-tending.

(3) Besides making recommendations for minimum quality standards, there is much work to be done by the Research Associations, in co-operation with organisations concerned with public health and nutrition, to find what qualities are desirable and necessary for goods in use, and to get these qualities embodied in the articles manufactured. This question is discussed further in Chapter 11 on Consumer Research.

10

BUILDING AND HOME DESIGN

THIS subject probably presents more problems and a greater complexity of conflicting aims than any other section of industry. There is an apparent conflict between the simultaneous need to provide good homes conforming with enlightened town planning schemes, and the supremely urgent task of constructing many dwellings within the shortest possible time although using a very depleted labour force.

The Housing Problem. The immediate problem in Britain and throughout large areas of war-scarred Europe, is to provide millions of new homes for the war-weary peoples. The housing problem is not new—it is a chronic problem which has become more acute as a result of the war.

In 1939 there were 12,500,000 houses in Britain; one in every three of these was over 100 years old. Over 200,000 families were then living in houses unfit for human habitation and certified for slum clearance; another 200,000 were living in overcrowded conditions as defined by the standards laid down in the Housing Act of 1936, which were admitted by most authorities to be very low standards. The war has made the situation much worse. By the end of 1944 over 200,000 houses were totally destroyed through enemy action; another 150,000 had been made uninhabitable, a large proportion being in such poor condition as to make their restoration unwarranted; more than 4,000,000 houses had been damaged and were still in need of repair. Houses are needed to replace those destroyed by bombing, to decrease overcrowding and to replace those scheduled in the slum clearance schemes.

Building Programme. It is generally agreed that about

4,000,000 houses are required in the first few years after the war, estimated to require 10–12 years in building. It is generally agreed that this target is practicable; but it is also argued that this period must be shortened. The Government estimate of 4,000,000 dwellings was based on the provision of 1,500,000 to 2,500,000 dwellings to replace slum dwellings, and 1,000,000 to give each family a separate dwelling, and so to avoid overcrowding. The Government estimated for its short-term programme the provision of 300,000 permanent houses "built or building" by the end of the first two years after the end of the war in Europe. This figure was based on a labour force of 350,000–380,000, which should be immediately available for domestic building, excluding repair work and other types of building. When it is recalled that in the inter-war years (1919–39), some 4,000,000 houses were built and that the total labour force available in 1939 was about 900,000 the magnitude of the task ahead becomes apparent. It is true that, with the Government's Training Scheme, the labour force is to be increased to 1,250,000, but this may take some years to achieve. The formidable problem of the production of building materials has also to be solved. Furthermore, many new buildings other than dwellings will be required, e.g. schools, factories for the production of essential goods, farm buildings to assist food-production, health and community centres, hospitals and nurseries. The use of building resources to provide for the cultural, social and health needs must be seen as part of the problem of raising the general standard of living.

Science in Building. Because of the very magnitude and the urgency of the problem, and because it is most unlikely that it will be satisfactorily solved by using methods which have already fallen short in the past, the production of houses is one that particularly calls for the full application of scientific methods. Science is needed not only, as in the past, to supply new machinery or new materials, but to investigate the whole range of building requirements and building methods in order to see what scientific principles are involved and how far this traditional industry can be brought in line with the more advanced industries which are based on science. The application of science to building is of course not new. Since 1921 we have had the Building Research Station of the Department of Scientific and Industrial Research, where very fundamental work has been done on such subjects as brick and concrete, weather resistance and insulation. More recently the Ministry of Works has introduced a Scientific Advisers' Department under the control of Sir Reginald Stradling, with the object of seeing that science is fully applied to all aspects of building. Committees have been formed to study building requirements, materials, structures and techniques. It must be admitted, however, that this work seems to be slow in getting under way, and has not yet had any notable effect on the building programmes. This is probably not the fault of the scientists, but of the Civil Service machinery which has not yet adapted itself to the idea that the Government must from now on undertake increasingly positive development functions in industry and cease to be merely the watchdog of the taxpayer.

Housing Requirements. The traditional nature of the building industry is shown particularly in the actual design of the houses that are put up. This design does not correspond to any ascertained needs, but has developed by a process of reduction and simplification from the designs of the houses of the wealthy of two hundred years ago. We are so used to inconveniently planned and designed houses that it never occurs to most of us that a house is, as Corbusier said, a living machine, and therefore can be planned as rationally as a motor-car or an aeroplane. Before this can be done, however, we must have some better idea of the specifications for living, how warm people need to be, how much air they need have, what rooms they need and for what purpose. The rational study of living conditions has begun in America and is now being undertaken in this country. Already it is apparent that, although a great improvement on the houses of the past, our houses are still far too cold and damp, and, what is more important in view of the certainty of an indefinite coal shortage, burn far too much coal far too inefficiently. They are not easy to clean and not equipped to reduce drudgery to a minimum.* The specifications for steadily improving types of houses scientifically arrived at will provide the guiding line to the development of building techniques in the field of housing.

Development of Building Techniques. Present-day methods of house building are the result of centuries of experience handed down from master to craftsman, from father to son. In the past, the craftsman shaped the materials on the job, and the design of the building was often not the direct result of his efforts. Later, doors and window-frames were made in workshops away from the site, and it was convenient to have bolts, hinges and ironmongery prepared in the local smithy. To-day this process of manufacture away from the site has been accelerated, and a larger proportion of the building job is carried out in factories, including the manufacture of windows, doors, staircases, steel beams and columns, sinks, baths and kitchen equipment. Brick and masonry walls are being replaced by steel frames and reinforced concrete. The use of precast plaster, plaster-board and fibre boards, tends to replace the craft of the plasterer and paperhanger. The building of large structures such as hotels, large blocks of flats and municipal buildings, are examples of the way in which present-day building technique differs from that of the past. The trend of building to-day is towards the factory production of the greater part of the structure.

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* It will be interesting to follow the results of the study of houses with experimental tenants which is being started by the Ministry of Works.

Prefabrication. Prefabrication naturally results when factory methods are used in the building industry. For prefabrication, a building is analysed into clearly-defined component parts which are manufactured away from the site under factory conditions using modern equipment and organised supervision. Many of these component parts are then built up into large sub-assemblies for dispatch to the site. Prefabrication makes it possible to erect a house with many fewer operatives and in much less time on the site than required by the traditional methods. With prefabrication the assembly methods are "dry," thereby eliminating the delay, formerly inevitable, in waiting for concrete, mortar and plaster to set and dry-out. The work is carried out in factories under cover, and the structures are designed to take the roof at an early stage in the assembly, so that the ensuing work at the site may be carried out under cover. The elimination of "wet time" means a great deal to the building operatives.

Prefabrication implies neither temporary nor permanent structures; it implies neither good nor bad building. Without adequate control prefabrication could lead to the worst type of mass-produced jerry-building. But under proper control and with the use of all that science can offer, prefabricated methods could produce attractive designs of permanent dwellings, well built, and with all modern comforts formerly available only to the few, at prices which the great majority of the people could afford.

Prefabrication is at present in its infancy and is passing through a period of growing-pains under difficult conditions. If the significance of this new technique be recognised, the standard of prefabricated houses a generation hence will be as different from to-day's prototypes as the modern car is from its predecessor of forty years ago. Prefabrication is not the panacea for all our ills; but it offers a partial solution. The problem of housing is so large that both traditional and new methods undoubtedly ought to be used. House production will no doubt ultimately become more and more prefabricated, with less call on the skilled builder as at present trained. House building should be reorganised as a new industry, using all the engineering skill that will soon be available. Munition factories, aircraft factories and motor factories should be partly diverted to the production of houses and kitchen equipment. Factory methods of inspection and quality control, which has proved invaluable in other industries, should be used in the building industry.

The question of site organisation must not be overlooked. Much of the advantages of factory organisation is lost if not accompanied by organisation of the work on the site. There should be a greater use of mechanical equipment, ranging from heavy machinery to light portable tools. Use should also be made of time and progress studies, which were widely and successfully used in factories, particularly during the war. In fact, the erection of the house should proceed as a continuation of the factory assembly-line, separated only by distance.

Building Materials. Science can help the building industry by facilitating the supply of materials and by developing new and improved methods of using them. New methods of construction have in many cases arisen as a result of the use of new building materials. By "new," it is not implied that these materials have only recently been discovered; instances could be quoted where the materials have been in existence for many years, but they have not yet been used on a large scale in house construction. The steel frame and the use of reinforced concrete have in themselves revolutionised building technique. Reinforced concrete makes it possible to span distances impossible with the traditional wood, stone or brick. Massive load-bearing walls are gradually disappearing and giving place to a light steel skeleton which takes the weight of the building on point loads, and which is clad on the outside with light-weight sheeting, serving no other purpose than to keep out the weather. This is a radical departure from traditional methods of building construction. The traditional brick wall, designed to combine the functions of strength, weather-proofing and insulation, does so inadequately according to modern scientific standards. With modern steel-frame construction each of these functions can be considered separately and only materials designed for each special purpose need be used. Thus the frame provides the strength and a wide choice of sheet materials is available for external and internal linings, the insulation being provided independently in the wall cavity. Steel-frame construction is common practice for building luxury flats, multiple stores, hotels and municipal buildings. Houses too can be built in this way, at relatively low cost, giving a greater degree of comfort and outlasting the best traditionally-built brick houses.

New possibilities have resulted from research into the properties of building materials. Concrete has been changed from a heavy, cold material into a light-weight product having good heat and sound insulation properties. Concrete made with foamed-slag, a by-product of the steel industry, is only one-third the weight of ordinary concrete. Light-weight foamed-concrete has been produced which is plastic in the liquid state and which can be easily poured. Aluminium and light alloys, as yet little used in building, may play an important part in the building programme, but there is a danger in conceiving their use as that of all-aluminium or all-plastic houses. Every material has its valuable properties which are needed for one or other function in building. Aluminium for instance is an excellent outer coating, but it would be better to restrict its use to this than to attempt to use it for frame or floors, for which it is not particularly suited. Plywood is another material with great possibilities.

By the use of light insulating materials it should be possible to arrive at a far more rational type of house. At present, on account of lack of scientific knowledge, we drag more than 100 tons of material to the site of every house, when less than 5 tons would produce a house which would be much warmer and take less coal to heat it.

Building Standards. Science can directly help the designer by providing the information on which standards of performance can be based. The Ministry of Works Committee on House Construction has already put forward provisional standards for thermal insulation, sound insulation, lighting and fire resistance. It has decided what heat-losses can be accepted as reasonable on economic grounds, and has fixed a standard of thermal insulation accordingly. The other problems are being dealt with in a similar manner.

Scientifically determined standards of quality for building materials and structures are needed to ensure that the performance of the completed buildings reaches a suitable level. Such standards have in the past been established by the British Standards Institution, usually at the request of manufacturers, but their adoption has always been optional. The work of this Institution is now being extended. Certain standards have been laid down for the physical constitution and properties of materials, and codes of practice concerning the use of some structural materials such as steel and concrete have been drafted. The adoption of official standardised sizes for items of equipment such as doors, cupboards, baths, stairs, fittings, is yet to come, although Manufacturers' Associations have in a number of cases agreed to their own standards. This standardisation is much needed in the building industry. During the war the value of standardisation as a means for increasing production, reducing costs and economising in materials and labour was recognised. The production of building parts is only possible through the adoption of dimensional standards. During the war the number of different types of steel windows was reduced by 80 per cent, and forty different types of domestic baths were reduced to five.

Home Design. The internal equipment of a house needs as much if not more scientific planning than the equipment of a factory. Science needs to be applied to make a house more comfortable to live in and to eliminate unnecessary drudgery and housework.

Standardisation on a smaller number of tested designs with an improvement in marketing arrangements so as to cut out distribution costs, would make many household aids come within the reach of many who have never hitherto been able to afford them. Standardisation should be extended to articles in daily use such as electric lamps (with guaranteed minimum length of life) and other electrical fitments, indeed any commonly-wanted article should be regarded as a fit subject for standardisation. This need not result in stereotyped articles. While the basis would be the best design in relation to the article's function, there would be scope for variety in colour and type of materials used. The recently appointed Council for Industrial Design under the Board of Trade could do valuable work on these lines.

Manual tasks in the home can be mechanised by using fractional horse-power electric motors. Washing-up and washing machines are practicable installations for every home, as well as the more commonly accepted cookers, refrigerators, electric irons, toasters and other household appliances. Large-scale production of these articles could help to bring the prices down. The possibilities of large-scale production would be increased if State-sponsored standardisation of design and materials were extended and enforced. The heating of rooms and water can be planned and provided on a district scale, the heat being produced at a central heat-generating station, using the otherwise waste heat of industrial plants or electricity generating centres. The effect of this would be to eliminate the dirt and drudgery of fires. In blocks of flats and groups of houses, it may be possible to incorporate a system of central refrigeration worked from the same plant as provides the central heating. A central refrigerating system would give more space in each freezing chamber for the storage of food, since much of the space in the individual refrigerator is occupied by the freezing unit, and the cost of operating a central refrigeration system would probably be lower than for the sum of individual units.

To ease the tasks of the housewife there should be a great extension of communal services, especially in catering and laundering, including special services for infants' napkins. The current criticisms of such services relate mostly to their quality. There should be a careful study of the factors influencing the optimum size of unit for providing such services, of the problems of cooking for large numbers, and of the effects of laundering on clothes. Here, too, the question of the price of such services should be tackled so as to make them available to all pockets.

Lighting in the home is often inadequate, resulting in eye-strain and nervous irritation. The simple step in solving this problem is to make electricity universally available at reasonable prices. In addition, study is needed of the amount of light needed for comfort in different parts of the home and for different activities; such studies were started by the War-time Social Survey. The suitability of fluorescent tubes for domestic lighting or other purposes also needs to be studied. Electrical efficiency in this field is not the only criterion, and attention should be given to the question of the quality of the light and whether or not strain is caused by its use.

Finally, the same criteria should be applied to the detailed design of the ordinary equipment of a dwelling as are applied in an efficient factory workshop. This should include the number and situation of built-in cupboards, convenient height of stairs, the placing of switches where they can easily be found in the dark, the design and placing of wash-basins, sinks and baths. Unnecessary corners, which form dust-traps and cause more work, should be eliminated. In kitchens, cupboards, shelves and kitchen-units should be carefully placed so that the housewife has all the tools of her job readily to hand.

II

CONSUMER RESEARCH

HOW TO ASSESS OUR REQUIREMENTS

Research into Consumer Needs. In the previous chapter some problems of home design were considered. This is one of many aspects of daily life for which research is needed to ensure that the articles produced are really fitted to perform their intended functions. During the last 300 years, scientists have worked out techniques of logical analysis and inquiry which give a more certain determination of fitness for function than merely individual judgment and experience can usually give. In order to make a correct decision, it is necessary: (*a*) to define accurately the end in view; (*b*) to determine the requirements that must be satisfied to achieve this end; (*c*) to find the possible different ways in which these requirements may be fulfilled; (*d*) to evaluate the different alternatives, their permutations and combinations. These processes may be carried out either consciously or unconsciously, but all are necessary. In the following pages the application of this technique to the needs of the individual user will be considered.

The user is, theoretically, free to choose an article he requires to serve his purpose, taking into account the balance between its usefulness and price. Such freedom of choice is supposed to ensure that the manufacturers who supply the best goods will make profits and continue to manufacture, while others will lose money and go out of business. This assumes access to and experience of a wide variety of products and an objective ability to discriminate between them. In practice the manufacturer has a very great influence on the consumer's choice, not only by the products he makes, but also through the vast organisation of advertisement. While the main spring of industry remains the profit-motive the emphasis will naturally be on the provision of the most "profitable" articles or services, whether or not they coincide with those of maximum real usefulness to the community. Hence in some cases the public does not get good value for its money. Further, people are not always aware of the most suitable goods for their needs, nor, if they are unable to obtain them, have they any method of protest save failing to purchase what *is* produced. Clearly it is important that some means should be provided for ascertaining the consumers' real needs, for transmitting these to manufacturers, and for ensuring that the finished articles are reasonably fit for the functions they are to perform. Already some progress is being made to discover what the consumer really needs. For many years manufacturers have initiated Market Research in order to find out what commodities the consumer will buy. The emphasis here is not on what the consumer needs but on what the manufacturer can most profitably sell and how he can improve his sales at the expense of his competitors. However, the consumer has occasionally benefited incidentally by such research. Market Research does not necessarily distinguish between the irrational prejudices and tastes of the consumer and his genuine needs.

How to find out what the consumer needs. In the U.S.A. the John B. Pierce Foundation has done much valuable work in studying the designs of houses from the point of view of the families living in them. This Foundation has carried out detailed studies, for example, of sound and heat transmission and their effects on the comfort of the dweller. It has investigated the space occupied in carrying out various household tasks, in order to determine the size of rooms required in different parts of a home. It has also studied the various personal preferences which people have for different types of dwellings, and the effect of such preferences on the way people use and furnish their homes. The ultimate aim is to find out what improvements can be made in the design of houses. The information gathered by the Foundation is freely published.

In Britain much good work was done by the Wartime Social Survey. This organisation was originally set up under the Ministry of Information to find out where the main shortages of goods lay, and how the public reacted to Government measures. It has, however, widened its scope to include a social and psychological study of a great many aspects of how people live. It has carried out inquiries into the amount of lighting used in a large sample of houses lived in by persons of various income groups. It has studied the relation between the subjective feelings of comfort of the people working, and the objective assay of total light generated in the room, the brightness of illumination at vital points, and the overall wall brightness. It has also inquired into the factors contributing to the feeling that a house is conveniently situated, such as the distances that people are willing to travel to work, shops or church, and, in some measure, the way that these factors may be balanced against other merits or demerits of the house. In their most recent work, the Survey has considered the implications of their findings in terms of the need for alterations in appliances, dwelling design or way of living, such operations as the preparation of food being considered.

Although it was attached to the Ministry of Information, the greater part of the work of the Wartime Social Survey was carried out on behalf of other Ministries. Under the name of the Social Survey, this body is to continue under the Central Office of Information. Certain modifications are necessary to make the best use of this Social Survey. Its most immediate need is for individual members to be able freely to publish papers on methodology, sociology and other subjects, and, more important, for the publication of the Survey's reports. At present the latter are the property of the Minister for whom the particular investigation is carried out; he may publish or suppress them at his discretion. By free publication of the Survey's reports, the public, thus informed of the work of the Survey, would be able to see that the accumulated information is used. At times there will be good reason why recommendations of the Survey should not be carried out, but it is far better that these reasons also should be made public, than that recommendations and counter reasons should alike be kept dark. "The right course to pursue may not be the best course technically; but it is impossible to know the right course to pursue without knowing the best course technically."

Much of the technique required for the study of consumer problems has been developed in the Operational Research Sections attached to the Fighting Services. The Services may be considered as consumers of the technical material supplied to them by industry. The first R.A.F. Operational Research Section originated as a body whose function was to study and report on the working of one particular system of technical apparatus, the radio-location system (Radar). But as the sections developed their scope was widened to cover the technical efficiency of all apparatus supplied, and, even more important, the efficiency with which these supplies were used. If "supplies" be interpreted so broadly as to include men as well as machines, the present scope of Operational Research may be realised. It now includes the study of the most efficient way of using all the resources of the Services or Command. In peace time the same technique can be used to study the most efficient ways of employing mechanised methods and of administering and organising our industries and social services.

Standards. After ascertaining the requirements comes the problem of fulfilling them. During the war the State laid down specifications for its own purchases and is now sponsoring standard specifications for housing materials and fitments. These have been worked out by the British

Standards Institution with the co-operation of the producing and consuming sides of the building industry. It is intended that these standards shall be considered the minimum permissible for all housing construction undertaken by the State or by local authorities, or for which any State grant is given. Standards have already been developed in connection with specifications for utility goods and they can be worked out for any other type of article. The application of statistical analysis to personal measurements and their inter-relationships would reveal not only average sizes but also the frequency of different sorts of variation. The large-scale production of suits and other garments could then take account of these variations in order to cater better for the persons who diverge markedly from average or stock sizes.

How to maintain standards. The operation of minimum legal standards implies some mechanism for protecting the consumer from dangerous and shoddy products. In Britain, food and drugs are covered by a number of laws, and during the war, control was extended to cover, for example, the meat content of sausages and the fat and bacterial content of milk. All types of milk are now tested fortnightly by the Ministry of Agriculture and consistent failure to reach minimum standards may result in prosecution by the Ministry of Health. Much of the control of quality of foods and drugs rests with the local authorities acting on the reports of the Public Analysts. This official supervision should be extended further to cover other articles as well as food and drugs. It should not be limited to prohibiting the sale of harmful products but should also prevent the sale of useless products, as has already been done for certain so-called remedies of dangerous diseases. The production of any useless article is a wasteful expenditure of raw materials, labour and machinery, and where the health of the nation is involved may have serious social consequences.

Advertisements. There should be some organisation able to examine the claims made by advertisements. Advertisement campaigns are designed principally to create markets for goods irrespective of their value to the public. In saying this it is not implied that all advertised goods are of poor value. But the force of an advertising campaign is no indication of the relative merit of the products, and in a certain proportion of cases goods fall grossly short of the claims made for them. This has been evident from legal proceedings since the introduction of standards for such products as egg substitutes.

In the U.S.A. two organisations exist, both originating from Consumer Research Incorporated (founded in 1929), which are non-profit-making and financed by individuals' subscriptions. They test wares of all sorts and advise their members. They publish fairly general guides on the principles of selecting goods, and confidential bulletins to members which give the quality and price of products on the markets, with factual bases for their assessments. It is probable that the development of high-pressure advertising in the U.S.A. has acted as a stimulant to the growth of these organisations, which are made possible only by the less stringent laws of libel in that country. Although the American organisations undoubtedly fulfil a useful function the information reaches only those consumers who are sufficiently interested and can afford to subscribe to the service. The greater part of the population, which is most susceptible to advertisement and least able to discriminate in buying, fails to benefit. More recently, the Federal Trade Commission has been empowered to prosecute manufacturers of foods, drugs, cosmetics and medical appliances either when these fail to comply with their respective advertisements, or when they are dangerous. In particular the use of the inter-State mails may be denied for the transit of such products. These restrictions do not influence business within individual States, which is the province of the State authorities.

A Consumer Research Council in Britain. The assessment of the needs of consumers and the protection of consumers from fraud must become one important section of the research work of our country.

The Association of Scientific Workers has come to the conclusion that such work can only be carried on adequately when a permanent organisation is established for the specific purpose of conducting research into consumer needs. The most appropriate form for such an organisation would probably be a Consumer Research Council (C.R.C.) under the administrative direction of a Committee of the Privy Council, with the Lord President of the Council as Chairman. This proposal was discussed and supported at the Trades Union Congress in 1945 when the following resolution was carried:

> "Congress recognising the importance of ensuring to the people adequate supplies of domestic and other consumption goods of proved quality and reliability at reasonable prices, instructs the General Council to press the Government to establish a Council for Consumer Research. The functions of this Council shall be:
>
> (*a*) To promote factual investigations into the utility, efficiency and cost of advertised consumption goods such as domestic equipment, food and medicaments.
>
> (*b*) To determine, through surveys and by other means, the quantity type and standard of goods required by the consuming public. The status and methods of financing this Council should be similar to those of the Medical Research Council. It should be required to publish its findings, which should be regarded as privileged comment within the laws of libel."

The Consumer Research Council would need to establish a special Department which might be called the Consumer Research Organisation (C.R.O.). The Consumer Research

Council should comprise permanent personnel consisting of staff of the C.R.O., supplemented by people who have already had experience in the required type of social science, and further supplemented by a small number of laymen chosen by the Lord President with a view to representing the consumer. The latter might be sought from, *inter alia*, the House of Commons and the Trade Union and Co-operative movements. Some scientists who have had experience in Operational Research should be included. A representative of the Department of Consumer Needs in the Board of Trade would also be desirable.

The C.R.O. should have considerable freedom of internal management, the workers having full liberty to develop their own plan of work. The C.R.O. should be expected to investigate problems within its scope passed to it from the public or from other Government departments; but it should be planned on such a scale that it would be able to investigate any problems that seemed pertinent to its members, and it should be expected to do so. Close liaison with bodies carrying out operational research on behalf of other Ministries (e.g. housing) and with laboratories working on relevant technical problems, would be essential. As much routine technical work as possible should be delegated to other laboratories.

In the work on the appraisal of consumer goods, the C.R.O. should at its discretion organise the examination not only of new products submitted to it, but of such goods already on the market as seemed to warrant investigation. Reports should be published of the results of all investigations undertaken. Reports on goods should be confined to quality, performance, and relative price; the C.R.C. should have no power of prosecution, even if its work revealed a breach of the law. Legal action must be left to the appropriate Ministry, which should also, where relevant, use the findings of the C.R.C. as a basis for the granting of licences for manufacture, sale or purchase of scarce materials.

The work on the study of consumer needs would be of wide scope, involving both surveys and detailed studies of how small samples of the population live. Great freedom should be given, particularly in the important fields of work. In addition to the presentation of factual reports, the workers on this side of the work of the C.R.O. should be encouraged to make recommendations where they felt they were warranted. All C.R.O. reports and recommendations should be made public, possibly in a regular journal for this purpose. An efficient publicity department should be maintained; without effective publicising of the results obtained by the C.R.O. the effect of its work would be jeopardised. The duties of this organisation would be:

(*a*) the publication of the formal reports (see above), which should be in as readable a form as is consistent with scientific integrity;

(*b*) the giving of wider publicity, through the Press, radio and other means, to the more important findings of the organisation, particularly where it could be shown that a significant improvement in the standard or amenity of living would be procured by the change of some widespread habit (cf. the M.O.F.'s wartime campaign for the better cooking of green vegetables);

(*c*) the education of the consuming public, to inculcate a critical spirit towards both goods and advertisements, and to help them distinguish the false from the true;

(*d*) the maintenance of good relationships with such bodies as Women's Institutes and Co-operative Guilds, both to pass on its findings and to gain wider insight into the consumer's problems.

To maintain such relations with these bodies and also with the Trade Union Movement, an Advisory Council might be set up, to include representatives of these and other interested bodies (including suitable employers), to meet at regular intervals.

It would be essential that the work of the C.R.O. should be planned ahead; it should therefore not be subject to the vagaries of an annual grant. The control of the finances of the C.R.O. could be most conveniently arranged by fixing each year its grant for the fourth year ahead (the money for the first four years of its existence being decided when it was set up). Thus decisions to reduce or extend its activities could be implemented in a regular and orderly manner, without the scrapping of half-finished projects that a fluctuating annual grant is apt to entail.

The Co-operative Movement. Certain other organisations could supplement the research into consumer needs carried out under State auspices. The Co-operative Movement is, by its structure, very well suited for conducting research into the needs of its own consumers. Co-operative production and distribution is undertaken in the interest of the consumers themselves, so that there should be no conflict of interest between producer and consumer to prevent the full utilisation of the methods of consumer research by the Co-operative Movement on behalf of its member-customers. Co-operative enterprise has tended to be conservative and disinclined to lead industry. Generally speaking the quality of its productions is good, but the taste and style leaves much to be desired. This may be one reason why, in a movement embracing 9,000,000 member-consumers, and which produces and markets food-stuffs, clothing, drugs, furniture, fuel, hardware and many other commodities, the average Co-operative household spends only a relatively small proportion of its weekly budget at the Co-operative store. The remedy is plain; the Movement should take action to find out what its members need, and why they do not always choose to buy Co-op. goods. The methods employed by the Wartime Social Survey and Operational Research Sections are not costly, relative to the results they achieve. It is estimated that £15,000 would pay for six major inquiries. A major inquiry into such a subject as clothing would include questioning about 2,000 households by competent inquirers asking individuals each about a hundred questions and spending about two hours in each household. Such inquiries could probably best be undertaken by the Co-operative Wholesale Society (C.W.S.) together with the Scottish Co-operative Wholesale Society, on behalf of the whole movement. In 1943 C.W.S. sales were £166.8 million, the Scottish C.W.S. sales £35.2 million and retail societies sales were £331 million. It can be seen that the cost of research into consumer needs is insignificant compared either with the present total trade or with the possibilities of increased trade in the future, and would help to ensure that the members were really satisfied with their purchases.

Technical Problems. Little has been said in this chapter about the technical advances required to satisfy the needs disclosed by the work of Wartime Social Survey or similar inquiries. Already in many technical fields there are State research organisations or Research Associations competent to solve the technical problems, if they are presented with them. In the past such research organisations have been more concerned with producers' than with consumers' problems. This has not been due to any lack of interest in consumers' problems but principally because no machinery is in existence which will present such problems to the technical research workers. The type of organisation suggested in this chapter could bridge this gap.

Industrial and National Planning. The methods of inquiry discussed are also applicable to the requirements of the industrialist who is a consumer of raw materials, intermediate products and the finished products of other industries. Many industries already employ such research techniques to ensure that their products shall be fit for function. But the extended application of such investigations would be essential if each of Britain's industries is to play its full part in relation to other British industries and those of the rest of the world. Further, such analysis must form part of national planning mechanisms. Wider problems than those of any one firm or even industry can be tackled in this manner. Any centrally conducted planning will need to rely on data gleaned by such methods. In road planning, for example, it is desirable to organise an investigation of road usage by measuring the rate of flow of traffic over various main roads, and also investigations of the causes of road accidents. Already a regular sample investigation of the health of the nation is being carried out. This gives an indication of trends in health long before ordinary statistical data covering the whole country can be collected and analysed and hence makes it possible to anticipate an oncoming epidemic in time to take preventive measures. In rehousing, a study of living habits and reactions to community organisation would give guidance in planning town lay-outs and the types of dwelling that the public prefers. In general a wide extension of the use of these still comparatively new methods can be foreseen. They may well become an indispensable instrument of democratic administration, since by their use, a government can speedily ascertain the will of the people.

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PROBLEMS IN ADMINISTRATION

IN the post-war economy of Britain efficiency in the control and direction exercised by the State over the various aspects of our national life will be essential to progressive development. This control may be operated by guidance, persuasion and instruction or by the nationalisation or public control of some industries. To carry out these measures efficient administration will be needed at all levels. While the day-to-day running of industry will obviously continue to remain in the hands of trained industrial executives and technicians, even in industries which may be nationalised, long-term direction can only be exercised by the appropriate departments of State. The key problem of administration will be to reconcile the two apparently contradictory necessities of delegating responsibility for decision and action to those who operate the economy, while maintaining control over long-term general policies and over the efficient and democratic execution of those policies. Much research into this problem will be needed. This extension of the State's function will place an immense responsibility and strain on the Civil Service.

During the war years, the Civil Service, augmented by many thousands of temporary Civil Servants, dealt fairly efficiently with the many problems of a war economy. Great capacity for administration was shown in the organisation of the production of war materials on an unprecedented scale and in dealing with the many new problems of civilian and Service life. But the administrative machine should not only be efficient, it should also be subject to democratic control and reflect the wishes of the public if it is to avoid the danger of bureaucratic dictatorship.

The Administrator. The function of the Civil Service is to translate into action the decisions on broad lines of policy that are taken by the Cabinet and Parliament, which policy must itself be formulated by advice derived from lower levels. The administrator, by his long experience and grasp of the details, is also in a strong position to advise and to influence the transient political head of a Ministry. Thus, though decisions rest in the hands of the Minister, the permanent officials are required to present him with facts and arguments on which his decision can be based. Hence the administrator's modes of thought, his social background and education are of great importance.

The results achieved by the Civil Service during the war were no discredit to the pre-war personnel who have borne the main strain. But considerable weaknesses have been disclosed in the nature, structure and composition of the Civil Service. The examination for entrance to the Administrative Grade, whereby the majority of this grade are selected, was weighted in favour of certain types of education: classics and the humanities rather than science (natural or social), the universities of Oxford and Cambridge as against the modern universities. And in fact a very large proportion of the Administrative Grade was educated at the so-called Public Schools (Eton, etc.) and at the universities of Oxford or Cambridge. This education and social background, however appropriate to the conception of administration as an Art rather than a Science, does not, in general, produce people capable of a scientific assessment of a problem, or of a truly democratic approach to the tasks of administration.

Together with the need for a new conception of the function of administration in a democratic community, the most essential change required in the Civil Service is that it should be permeated by a scientific spirit. This can be secured ultimately only through changes in the educational system. Relatively few administrators are needed with highly specialised scientific training, but all should have acquired a scientific outlook as part of a general education. An administrator should automatically approach any problem posed to him with a series of questions: What exactly is the aim in view? What are the available relevant facts? What further facts are necessary to give a complete set of data? How far are these facts obtainable and at what cost in time and effort? Can one base a reasonable decision on the existing facts? What result would flow from such a decision? What is the possible margin of error of such a decision? What greater certainty could be obtained by collecting more data? Would the additional precision be sufficient to justify the additional work? What alternative policies are there and what would be their consequences?

Unfortunately such a logical approach is all too rare. The potentiality of such an approach is not confined to any special category of persons; but many suitable entrants are excluded from the Civil Service by the requirements of the Administrative Grade examination. Methods of recruitment should be relaxed in order to permit interchange with the service of local government and of semi-public institutions such as the Port of London Authority, the L.P.T.B. and the B.B.C. Furthermore, recruitment to the Civil Service directly from the universities and at a relatively early age is not always desirable. Previous experience in other walks of life would undoubtedly produce greater adaptability, maturity of outlook and appreciation of the repercussions of policy decisions.

Research into the Problems of Administration. Within the Civil Service there should be an organisation to study the techniques and efficiency of administration. Already Organisation and Methods sections exist in each Ministry. These sections have the nominal task of advising on: the design of organisational structures and procedures; the effective use of staff; the application of mechanical aids such as calculating machines; the lay-out of forms (but not on their effectiveness for the collection of data). The type of organisation required should link together Organisation and Methods sections, having more comprehensive functions than at present. It should be responsible either to the Cabinet Secretariat or to some newly-created Civil Service Establishments organisation, divorced from the Treasury and based perhaps on an expanded Civil Service Commission. Its functions would include the provision of a pool of advisers competent to aid administrators in formulating problems and in gathering the necessary data. The organisation should include a section engaged on research into the problems of administration and in devising criteria of efficient working. It should be able to advise on the use of mechanical aids such as Hollerith machines and calculators, and on office methods in general. The establishment of objective scientific criteria of efficiency would release the Civil Service from the restrictive criterion represented by Treasury control of expenditure.

The Training of Administrative Personnel. Among other organisational changes which would be valuable would be the more frequent use of scientists on Standing Advisory Government Committees. This would enable men who would not consider full-time State employment to devote a part of their time to public service. Such committees, too, would do much to improve mutual understanding between full administrators and technical experts. Training should be arranged inside the Civil Service for all officers in the Administrative Grade. This training should include courses on scientific method, statistical technique, mechanical means of handling information and their application to efficient administration. It will be particularly important in the future for Civil Servants to have a broad technical understanding of industrial and commercial practice. This would enable them to deal more adequately with problems of production, to call in expert assistance at the proper stage, and to formulate correctly the problems for the experts to solve.

Administration a Human Problem. Above all the administrator must realise that the end results of his actions fall upon human beings; their wishes, dislikes and human foibles are the most important factor of all. Scientific administration is not something cold and inhuman. On the contrary, since the reactions of the man in the street affect, and are affected by, the operation of administration, they must be regarded as an essential part of the data on which decisions are based. The techniques of opinion-testing and fact-finding, such as used by the Wartime Social Survey, are invaluable in enabling the administrator to assess these factors. The scientific organisation of administration would reduce or even eliminate some of the more irritating features of "bureaucracy," such as the asking of irrelevant questions or of questions which have already been answered. Fewer forms and greater understanding would result from better administration. The Whitley Councils should be encouraged to discuss departmental problems, as was indeed intended when they first were set up. Joint Production Committees have proved their worth in industry and the Whitley Council might well play a similar part within the Civil Service. The measures suggested above are means for raising the technical efficiency of administration only. As Civil Servants, administrators are subject to decisions taken on political, non-technical grounds. Ultimately the responsibility for these decisions lies with the electorate; the control of the operation of these decisions is a problem of the working of British democracy.

Local Government and Industry. The problems of scientific administration have been considered so far mainly in relation to central government machinery. Similar problems exist in regional and local government and in industry. The quality of administration by local authorities in Britain is in many places very high, but, generally speaking, it needs considerable improvement. In industry, before the war, administrators were concerned primarily with the assessment of market conditions and forecasts, financial operations, etc., fields in which many of the foregoing comments have full validity. It seems likely that the extension of State control of investment, the location of industry, and the scale of production in various fields, will tend more and more to limit the tasks of the administration in industry to the more technical ones of production, organisation and control, process planning and industrial welfare. In these fields, "scientific management" has had in the past an ominous sound for the workers, with their experience of the ways in which various speed-up and "rationalisation" systems have been applied to their detriment. Methods of administration and organisation based on a scientific appraisal of facts and resources should have a great part to play in lightening labour as well as in raising the productivity of British industry. They must not be applied in such a way that the workers are penalised.

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THE FUTURE OF FUNDAMENTAL RESEARCH IN SCIENCE

THE main theme of this book is the use of science in meeting the needs of the people. Hitherto the discussion has mainly attempted to show how the application of scientific knowledge and method could directly increase British industrial efficiency, and help to improve the health, nutrition, homes, in short, the lives of the people. Applied science, the development and application of already existing knowledge of the physical, chemical and biological properties of nature in order to fulfil given requirements for technical progress, has been the main topic of discussion. It is now necessary to consider what is known as fundamental research in science. This is scientific research which aims at the extension of fundamental knowledge about the world of nature: inanimate and animate nature, man and his mind, and the universe he inhabits. Fundamental research is not normally directed to immediate practical application, which is the role of applied research. The distinction between fundamental and applied research in science is not clear-cut, as will be seen, but is real enough to be useful in discussing Britain's scientific effort. In the U.S.S.R., admittedly with a different organisation of society, it has been possible, through the centralised planning of scientific research and development, for the community to set long-term objectives of application whose achievement will involve much scientific research of the most fundamental character.

The Development of Fundamental Science. Science, the body of continually growing and developing scientific knowledge, is man's organised and continued effort to understand and control his environment, and fundamental research is the means whereby this understanding is deliberately widened and deepened. The whole process of the growth of scientific knowledge is cumulative; it has shown that the world of nature is a unity. As different fields of knowledge extend they touch and then unite when more fundamental principles are found to underlie them. The union is thus, in some respects, a simplification, since a single principle is then able to deal more accurately with diverse material, or with a wider range of phenomena, than could earlier and less fundamental principles. The laws concerning the way bodies fall and move, discovered by Galileo, Newton and others, culminating in the Newtonian mechanics of the universe, provided the theoretical basis for the understanding and development of many mechanical inventions (machines, means of transport, exact navigational methods). Similarly it was not possible deliberately to change one substance into another, as in chemical industry, or to understand the combustion of fuels for power supply in industry and transport, until fundamental research had established that, for chemistry, all matter is composed of atoms. The theoretical basis of modern chemical industry is thus that wide generalisation and summary of the chemistry of the elements known as the atomic theory. Fundamental research extending over many years has yielded a knowledge of the structures of the atoms themselves, and of how these structures may be changed. The application of this knowledge has culminated, for the present, in the construction of the atom bomb, and this knowledge of the fundamental properties of matter may be expected to make available a potent source of energy, hitherto untapped by man, for the peaceful development of the world.

In our own time the bridge between physics and chemistry has been firmly established on the basis of quantum mechanics, although it will still be some time before the more complex chemical systems can be adequately analysed in these terms. Biological studies are at a more primitive stage, indeed the various branches of biology only touch one another and chemistry very imperfectly at present, although it is already possible to see dimly the way in which these bridges will be built. Physics, in contrast, is at a more advanced stage of integration, permitting the design of much apparatus, industrial equipment, etc., to be done entirely on paper and without experiment.

It would appear to be clear that an increasing control over nature depends upon increasing man's real understanding of nature, that is, upon the prosecution of fundamental scientific research. Without this, technical progress might continue for some years but would gradually become less and less. It should always be remembered that the great war-time triumphs of applied science such as radar, jet-propulsion, the atom bomb and the large-scale manufacture of penicillin were based on fundamental research conducted long before the war. In the policy put forward in this book, the securing of adequate support for fundamental research is to be regarded as the key to all the other proposals.

Further, in expanding scientific activities in Britain the present distribution of forces is such that fundamental research should undergo a greater proportionate expansion than applied research. It would not be sufficient, however, merely to increase the funds available for fundamental research; attention should also be given to the directions of its development.

The Directions of Scientific Research. The forces which determine the lines of fundamental research come mainly from two sources. Problems may occur, for example at various stages in the development of industrial technique, whose solution demands new fundamental knowledge of nature; similarly in efforts to control disease and to develop agriculture. These problems may suggest new fields for fundamental research. The impulse from such directions may be very important, especially at early stages in the history of a science or in the differentiation of a new field of science. When the whole body of natural knowledge has grown to science as we know it, new fields and directions for fundamental research are suggested by the internal development of science itself, as the study of the atoms of chemistry and their regularities expressed by the atomic numbers and the periodic table suggested the study of the structure of the atoms themselves.

Any field of study that is developed in science tends to pass through successive stages: (*i*) description; (*ii*) systematisation: (*iii*) in most fields, active experimentation; (*iv*) generalisation; (*v*) application of the generalisation to other branches of science and to technology: (*vi*) a more detailed analysis of the phenomena covered by the generalisation. Particularly at the stages *v* (application) and *vi* (further analysis), whole new fields of study may be opened up, or investigation may be extended to phenomena at the margin of the original field of study. These new fields of study may appear to hold out lesser or greater hope of eventual importance for the progress of mankind, but none should be neglected, because science is a unity, and it is to be expected that a discovery in one field will have repercussions elsewhere. It would be very undesirable if fundamental research were not actively encouraged in those fields where direct social application is less obvious—e.g. astronomy. The objective should be a balanced development of man's knowledge of nature as a whole.

What is required in deciding on a financial and allocation policy for science is a knowledge of the total requirements as suggested both by the momentum of internal development within science and by problems arising in industry, in life, and from the setting of social objectives. There should be a liberal policy to provide sufficient finance to allow of work in all fields of science. Where priorities have to be made for reasons of social (not sectional) urgency, greater emphasis should be placed, at least temporarily, on those fields of research which promise the greater results for the economic advancement of the community.

A time can be envisaged when the main economic needs of society have been satisfied. Scientific research can then be prosecuted "for its own sake" and for its cultural value. At present this cannot be regarded as the primary reason for demanding greatly enlarged resources for fundamental investigations of nature. Nevertheless, simply to achieve the economic objectives which society is setting itself, will enhance, rather than diminish, the cultural quality of all scientific endeavour.

A direction of emphasis in scientific research, as outlined above, could only be given by a central co-ordinating body; not by the often contradictory and unbalanced forces of industrial competition, or by a host of individual predilections for particular topics of research. Such a central body could be responsible for: the allocation of funds for research in particular fields; the starting of new research institutes; the encouragement of effective liaison between different branches of science, between technique and theory, and between fundamental and applied research. In Chapter 15 some suggestions for doing this will be discussed; here only the policy itself is considered.

It has been urged by some that the unpredictability and novelty of many really great scientific advances preclude any effective planning of research. This attitude shows, it may be suggested, a mistaken idea of the purpose of planning. The purpose of planning is not to restrict research to apparently profitable fields, but rather to ensure that adequate facilities are provided where they are needed. By framing a programme of research which ensures that investigations are carried out which have not hitherto been done for lack of facilities, but which it is seen should be done, the chances of unexpected and important discoveries being made will be increased. It must be remembered that fundamental research in Britain has been largely conducted in university departments, where the division of science according to subject matter is often 50 to 100 years out of date. This has accentuated the gaps in man's knowledge of nature, because the classical divisions impede flexibility, liaison and co-operation. This makes it important that one of the first organised measures to be undertaken should be a concentrated effort to fill the gaps. Centralised direction and co-ordination of fundamental research could also produce a more purposeful drive in fields where industry does not provide sufficient impetus, and could preserve a balance between very long-term research and that likely to have more immediate applications.

Fields of Science requiring Development. Some gaps in our knowledge of nature are due to the backwardness of particular industries whose technical requirements would otherwise have forced the pace of fundamental research in these fields. Agriculture is an outstanding example. There is a great lack of knowledge in plant physiology and biochemistry (particularly of the photosynthetic process), and of the physics, chemistry and biology of the soil. This cannot be attributed to inherent difficulties in these subjects, since there has been at the same time spectacular progress in corresponding studies of animal physiology and biochemistry, stimulated by the insistent demands from medicine. All biologists will be aware how little effort has been devoted even to a preliminary mapping of the scientific problems which are fundamental to food production. It is only quite recently that the Agricultural Research Council has begun to finance research into some of these matters. This policy, if followed up on the necessary scale, could alter the whole character of biological science in Britain. Other similar examples occur in other branches of science. Our ignorance of silicate chemistry, geochemistry and the chemistry of coals and shales may be traced to backwardness in the mineral-extraction industries. It might be expected that studies of the mechanism and kinetics of chemical reactions and of the thermodynamic equilibria of physical systems in relation to molecular structure would be much more advanced if much production in the chemical industry were not still too dependent on antiquated and inefficient plant.

Other activities insistently demand to be undertaken because of some striking discovery in technology or applied science. Here there is a tendency at present to devote disproportionate resources to the empirical working out of a discovery, and not to expanding the fundamental science that lies behind it. Chemotherapeutics is a striking topical example. Had a fraction of the energy devoted during the last ten years to the empirical discovery of chemotherapeutic agents been diverted to a study of the mechanism of action of these agents, the stage of development of this branch of medicine would probably be much further advanced. Studies of the fundamental aspects of the structural chemistry of the more complex naturally-occurring substances might similarly lead to dramatic results in fields where empirical discoveries have already opened a promising path.

Organised encouragement could also be given to the application of new techniques for research purposes: to develop them and to make them available on the widest scale. Thus, to give a topical example, the use of elementary isotopes—stable or "artificial radioactive"—is having very profound effects on the technique of research in many different branches of science; the same may be said of the electron microscope and related devices. Here new techniques often lead to a very quick clearing up of chronic problems for settling which older methods had proved inconclusive. Organised provision for the development of new research techniques and for making them generally available would be welcomed by research workers in all fields (see Chapter 15).

Special laboratories for the study of particular forms or states of matter—e.g. silicates, fibres, metals, proteins, the liquid state—could play a very useful part in linking fundamental with applied science. More important than the concentration of special equipment and apparatus in such laboratories would be the benefit from having in them workers whose skill and experience would increase faster than at present owing to their being brought in contact with a far wider range of experimental material.

These might well grow out of existing institutions such as Research Association laboratories, but in that case they should be separately administered so as to remove them from the necessity of dealing with day-to-day problems.

Making a broad survey of our knowledge of nature, four main areas of ignorance are apparent towards which research should specially be directed:

(*i*) The range of subatomic phenomena.
(*ii*) Phenomena concerned with dimensions greater than the atomic and less than the microscopic.
(*iii*) Relations between nerve physiology, behaviour and psychological phenomena.
(*iv*) Foundations of the social sciences.

(*i*) *Sub-atomic Research.* In sub-atomic studies it can be anticipated that soon from one of the "purest" branches of science will emerge outstanding technical advances in the constructive use of intra-nuclear energy. The construction of the Atom Bomb unites in one striking example an illustration of many of the conceptions put forward in this book. In the first place it shows what enormous and rapid strides can be made by scientific research and technological development, when a sufficiently big organisation of research, development and production is created and given the necessary financial backing. This in itself is the most brilliant example to date of the potentialities of fundamental and applied science when properly planned and organised.* It may well be that this lesson is more important for society than the fact that this newly-tapped source places inexhaustible energy at man's disposal. Secondly, the development of the Atom Bomb underlines the necessity for these studies and their applications, having such great constructive *and* destructive potentialities, to be subjected to adequate social control, both national and international. Moreover, since it has been through State and (partial) international organisation of the work that the development has been brought about, it is right and vital that the peoples should derive the benefits from it; it is too big and is too important to the life of every citizen for exploitation by private, sectional or monopoly interests to be permissible. Thirdly, for the first time in the history of mankind the discovery and development of a primary energy source of revolutionary potentialities, equivalent to the discovery of fire, has taken place at a time when its social exploitation is possible and clearly necessary.

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* This great advance in applied science was made of course at the expense of stopping almost all other work in nuclear physics; the scientific personnel to do both was lacking.

(ii) The Study of Phenomena at Dimensions between the Atomic and the Microscopic. In the group of studies of phenomena occurring in matter at dimensions between the atomic and the microscopic there is to be secured an improved understanding of the working of living organisms. This will throw much light on their physiology, heredity, nervous mechanisms and behaviour. In the non-biological field, there may be secured an understanding of the properties of materials which may revolutionise structural, electrical and mechanical engineering and architecture. Here the use of the electron microscope may open a field as large as the microscope did in the seventeenth century.

(iii) Relations between Psychology and Physiology. The development of electrophysiology and the direct measurement of nerve impulses can now be linked with sensation, movement and behaviour. The opportunity for study in these fields has been very limited and has depended only on the work of a few enthusiasts. The importance of having

a psychology soundly based on measurable phenomena would justify a much greater research expenditure.

(*iv*) *Foundations of the Social Sciences.* The growth in importance of the social sciences as practical adjuncts for every type of industrial and administrative task of the future has not been accompanied by anything like the amount of scientific research that is needed. At the moment sociological research only receives about one per cent of the total expended on research. It is essential that more work be put into this field and that part of it should go to a really critical examination of the bases of the subject and of the way in which it is related to the natural sciences. A beginning in this direction has been made by the Social Sciences Committee of the Association of Scientific Workers.

Support for Fundamental Scientific Research. Support for fundamental research is required of such character that it will give a well-proportioned development of all branches of natural knowledge. Hitherto in Britain this development has been hampered because much of the finance of fundamental research has come directly from individuals and organisations interested primarily in industrial profit-making or in the development of limited fields, without regard for the balance of the whole. Moreover, some institutions and interests inherited from the previous century have fostered mental inertia, because they were conceived in terms now out-moded or were not flexible enough to respond to new requirements for creative research. Research has thus been directed along rather narrow channels, particularly in the fields of physics and chemistry. There is a danger of this tendency being accentuated in the future. Many proposals from "industrialists" have been made* during the last few years for increasing the quantity of scientific research. It is clear from an examination of these proposals that research is envisaged as a sort of talisman for getting quick results cheaply, for producing good "selling lines" with a minimum of modification to existing plant. Lip-service is paid to fundamental research, but increased provision for it, from the hands of these benefactors, would probably mean an intensification of the disproportions which already exist, in the hope that this would justify itself by giving rise to "get-rich-quick" applications. Thus in chemistry the emphasis is on finding new compounds which can be made by old methods rather than the converse.

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* e.g. the Report of the Industrial Research Committee of the Federation of British Industries, October 1943.

These are the real issues concerning the future of fundamental research, and hence the whole progress of science and technique. Science is and will remain subject to control by society or by some section of it; it is better that it should be, however indirectly, by the community as a whole.

Recently the Royal Society has concerned itself with the future of fundamental research. An inquiry has been conducted into the requirements of fundamental research in the different universities and institutes. A report has been issued which was discussed at the Imperial Scientific Conference in July 1946, and has been the subject of recommendations favouring increased support for fundamental research. Some central organisation appears to be necessary to guide support into neglected channels.

From the point of view of the individual scientific worker the organised development of whole fields of science will not only permit, but also necessitate, roving commissions for a great number of research workers, more, probably, than can immediately be found to fulfil them adequately and imaginatively. With a development of science as is envisaged here there will be a freedom for the individual research worker in conditions of work, and in range of choice both of "subject" and "problem," far greater than has ever existed before.

14

THE PLANNING AND FINANCE OF SCIENCE

THE proposals made in earlier chapters call for a considerable expansion of scientific research and development. In most cases this expansion will mean the expenditure of much more money than before the war. In many cases new forms of organisation would be needed in order to make the most efficient use of scientific man-power and to apply results rapidly and effectively. Important financial and organisational changes would be needed to put into practice the policy already outlined. Science in its widest sense, including research work in fundamental and applied science, development, process-control and testing all need to be considered.

Although science is now regarded as a national asset, and in all the major countries is supported by industry and by the State, the rapid development during the present century has been very uneven. Countries differ very much in their total expenditure on science, in the sources of the revenue devoted to science and in the forms of organisation which have been set up to foster and co-ordinate scientific work. It is difficult to get comparable figures for the various countries, either for total expenditure on all scientific work or for total expenditure on research. An estimate* made in 1938 for the total expenditures on science, as percentages of the national income, gives the following figures: Britain 0.1, U.S.A. 0.6, and U.S.S.R. 0.8. The estimate for Britain may have been low and is certainly too low for war-time expenditure; it is nevertheless admitted that Britain has been spending relatively far less on science than other major countries. Some people have discounted such estimates, saying that scientific advance cannot be directly correlated with the amount of money spent. It is true that it is the ability of the scientists which in the last analysis most determines scientific advance, yet inadequate finance and insufficient facilities may greatly impede fundamental research and may cause scientific discoveries to be stillborn. Unless Britain takes steps now to increase the total expenditure to at least 1 per cent of the national income, then in ten to fifteen years' time, when the effects of the increased expenditure of the other countries becomes apparent, British science will be found to have lagged, and Britain might become a third-rate power.

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* J. D. Bernal. *The Social Function of Science* (London, George Routledge & Sons, 1939).

The organisation of scientific work in Britain has developed in rather piecemeal fashion; only in recent years has much attention been paid to the problem of national co-ordination and planning. The Association of Scientific Workers, as early as 1942 during the war, put forward plans for a central Scientific Planning organisation and in September, 1942, a group of 120 Members of Parliament put their names to a motion calling for a Central Scientific and Technical Planning Board to organise science for war purposes. There has been much discussion since by many organisations and it is part of the work of the Lord President's Committee on "Scientific Manpower," set up in 1945, to consider the best method of co-ordinating our scientific effort in order to make the fullest use of our resources. Although this proposal was never implemented, it was widely discussed and support was given to it by scientists in many fields.

The kinds of problems to be solved in the post-war years are different from those of war; but it is no less necessary to direct the forces of science in the most efficient manner. The first requirement for any central organisation is that it shall be capable of directing scientific work into the correct channels. It should be able to plan the short-term work so that all urgent questions of relief and reconstruction receive adequate scientific and technical assistance, and at the same time to plan for long-term research work and production-development. Britain cannot afford to be without a bold and vigorous policy for science at the present time. It follows that the kind of organisation needed is one which will cover all aspects of scientific work and which will be intimately connected with the Government so that it can formulate and carry out a policy for science in full accord with the country's needs. The central co-ordination and planning of scientific development does not entail the regimentation of individual scientific workers. Within a general framework which would emphasise the fields of science needing special attention, individual scientists should be given the maximum freedom in choice of subject, opportunity for frequent discussion and revision of programme.

THE PRESENT ORGANISATION OF SCIENCE IN BRITAIN

There exist in Britain a number of departments set up by the State for the furtherance of science, including the Department of Scientific and Industrial Research, the Medical and the Agricultural Research Councils. In addition there are industrial organisations and those in the universities and technical colleges. The parts all these play in the scientific work of the country are considered in the following paragraphs.

The Universities and Scientific Research. The greater portion of fundamental scientific research in Britain is carried out in the universities; some, probably less than one tenth of the whole, is carried out at variously endowed research institutes, State laboratories, Research Association laboratories, and by a few of the larger industrial firms. In the U.S.A. a far larger proportion of fundamental research is carried out by industry, by such firms as the General Electric Company, the Bell Telephone Laboratories and many others. While it appears desirable that in Britain a larger proportion of fundamental research should be undertaken in industrial and State laboratories, it is from the universities that most of the advances in fundamental science may be expected to come, at least for many years.

The universities have a dual role: the training of future generations of scientists and the prosecution of fundamental research. Here only the question of the provisions for fundamental research will be discussed; the educational aspect is discussed in Chapter 18. It is of great importance to university teaching that the whole teaching staff should be able to engage in research to some extent. As soon as possible, arrangements should be made at the universities to enable the teaching staff to spend on an average half their time on original investigations. The prosecution of fundamental research depends primarily on obtaining the services of people who possess the necessary flair. This will certainly not be a limiting factor; university research before the war did not suffer from lack of suitable men and women but from a lack of finance for equipment and building schemes, and a lack of skilled technicians to assist competent research workers.

The universities possess certain endowments, and of late industries or individual firms have made some financial contributions, but the increased finances required must be expected to come almost entirely from State funds. The direct State assistance for all University purposes was increased in the Budget of April 1946 to £9,540,000 for 1946–7 (an increase of £3,800,000 over 1945–6); it is administered by the University Grants Committee, which is a committee of the Treasury. Local authorities and other Government departments provide another £1,000,000. The provision of increased financial allocation for research must be considered together with the proposals for increasing the number of students and for increasing the proportion of teaching staff to students. It is suggested later (Chapter 18) that the total number of scientists needs to be doubled in the next fifteen years*; and further, the proportion of teaching staff to students for all universities requires increasing to give the ratio of about five students per member of staff which obtained in one or two universities before the war. With this must be taken a recommendation that the salaries of university staffs should be increased considerably, reaching at least 50 per cent above pre-1939 figures eventually. It has long been recognised that the salaries of university teachers are entirely out of accord with the social value and prestige of the profession and with the mode of life consonant with it. A further reason for increasing university salaries is to counteract the attraction of higher salaries in industry and the Civil Service, without which the best brains will be lost to the universities. Far more post-graduate scholarships are also needed to enable the more promising students to continue at universities.

The increased call on State assistance will be a heavy one. The annual expenditure should increase roughly in proportion to the expansion of the universities. Bearing in mind the high cost of scientific equipment it is suggested that the Government Grant for current expenditure should reach at least £10,000,000 by 1950, £20,000,000 by 1955, and £25,000,000 to £30,000,000 by 1960. The necessary increase in capital expenditure is more difficult to estimate, but the acute shortage of buildings for laboratories and libraries is such that at least £10,000,000 should be spent by 1950. It is to be hoped that such building will be given high priority. Over the period 1945–60 the necessary capital expenditure may be estimated at £40,000,000. These sums may appear large by present standards, but such expenditure would bear abundant fruit.

For the better co-ordination of research at the individual universities, it is suggested that University Research Committees should be set up whose function would be to care for the general development of research in the university, to decide priorities in the building of new departments, to advise on the creation of new chairs, to present the total research budget for the university to the University Grants Committee, and to exercise general supervision over research committees which could be set up in the different science departments. It may be further suggested that there should be a Universities Council, representative of all the universities, to act in part as an advisory committee to the University Grants Committee.

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* The acute shortage of scientists and need for increased staffs and better remuneration has now been recognised in the report of the Barlow Committee on "Scientific Manpower," Cmd. 6824, H.M.S.O.

State Science

Many Government Departments have their scientific divisions; some now employ a fairly large number of scientists. Apart from the Service and Supply ministries, the most important sections of Government science are those controlled by the Department of Scientific and Industrial Research, the Agricultural Research Council and the Medical Research Council. The last three bodies are responsible to Committees of the Privy Council. There is also the Development Commission, set up in 1909, when, under the Development and Road Improvements Act, a fund was established for the purpose, *inter alia*, of "aiding and improving agriculture and rural industries, by promoting scientific research."*

Under the various Ministries, scientific work is organised as part of the Civil Service machinery of the department concerned, and as such the organisation has been subjected to much criticism. As far as the individual scientist is concerned there are valid points of criticism to be made. Thus, in the higher posts Civil Service scientists are paid less than in industry (although the average salary compares favourably with that in some industries); their work is less free than at a university or research institute, and they have less chance to publish their work. Promotion by a fairly rigid system of seniority gives the Civil Service scientist little reward for outstanding work and often means that he will have to leave the laboratory for administrative work if he wishes to get on.

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* For details of the State organisations of science see the White Paper on Scientific Research and the A.Sc.W. Memorandum "*Science in Government*" (1946).

For reasons such as these, many of the best scientists have been unwilling to enter Government service, although it is true that they have a relatively secure tenure of employment. Nevertheless, particularly during the war, with an influx of many new people into the Service, State science has had brilliant achievements to its credit. In the post-war period it is clear there will be intense competition for scientists between Government service, industry and the universities. Only by improving the attractiveness of a scientific career in the State service will the Government obtain a fair proportion of the most promising and enterprising scientists. The new scales for scientific staffs based upon the White Paper, *The Scientific Civil Service* (Cmd. 6679, H.M.S.O., 1945) have given certain improvements but are still unsatisfactory.

Certain kinds of scientific work, for example research on armaments, should be developed by the State, and it will be to the advantage of the country to employ first-rate scientists in the various departments concerned. Immediate steps which should be taken include: raising the scales of salaries, making available more senior posts which do not involve leaving research-work for administration, and encouraging scientists to publish as much as is compatible with security. An alteration of attitude is also needed by giving the scientists more freedom in their work and making them less bound by petty restrictions.

Most of the research work carried on during the war years was of necessity short-term, intended to achieve results quickly. Some of the State departments are now not only well equipped but well staffed to undertake post-war programmes of fundamental research. If this policy is to be adopted, however, serious thought must be given now to retaining and to recruiting able workers. The inspection departments of the Service and Supply Ministries have grown and an enormous volume of war material has passed through the hands of the scientists in these departments. The experience gained in this work can be turned to good use in considerably extending State inspection of consumer goods for civilian use. (See Chapters 10 and 11.)

The Medical Research Council (set up in 1920) is appointed by, and is responsible to, the Privy Council Committee for Medical Research. Under its constitution it is empowered to pursue an independent policy for the advancement of medical research. It administers its own funds, maintains the National Institute for Medical Research, and provides members of its staff to work at hospitals or other research institutions; it also gives a number of personal grants and grants for individual investigations. It has sub-committees to deal with various fields of investigation. The establishment of a National Health Service will call for very much more medical research (see Chapter 8). There should be a substantial increase in the grant to the Medical Research Council, rising steadily over ten years as more workers and buildings become available, and with an extension of its fields of activity. The Medical Research Council should be enabled to employ a larger percentage of permanent staff entitled to pension rights, rather than to increase the number of workers dependent on grants of uncertain length of tenure.

The Agricultural Research Council (set up in 1931) is responsible to a Privy Council Committee for Agricultural Research. It supervises the greater part of agricultural research in Britain and spends its grant on research at its own institutes or in aiding research elsewhere. It provides the greater part of the funds of more than twenty Agricultural Research Institutes in Britain; some of these are attached to universities or are nominally controlled by agricultural or horticultural associations. Recently the Agricultural Improvement Councils for England, Wales and Scotland were set up by the Ministry of Agriculture and the Department of Agriculture for Scotland, to bridge the gap between research and practice. These Improvement Councils link the Research organisations with the Advisory Services, the Central Laboratories for Plant and Animal Pathology, and certain other organisations of the Ministry and the Department of Agriculture for Scotland. In this way they assist not only in the rapid application of research results, but in the detection of problems requiring investigation. In agriculture not only is there scope for much more research but also for a very great extension of the advisory services in direct contact with the farmer. In this field it may be suggested that the volume of research should be approximately doubled and that the advisory services should receive as much as a tenfold increase in personnel and facilities. This would require a corresponding increase in the expenditure of the Agricultural Research Council and the Ministry of Agriculture. For the additional personnel required it should be possible to absorb a number of scientists formerly working in other fields, such as the war-expanded explosives industry.

The Department of Scientific and Industrial Research (D.S.I.R.), set up in 1917, is responsible to the Lord President of the Council. It maintains a number of research establishments, among which are the National Physical Laboratory, the National Chemical Laboratory, the Building Research Station, the Geological Survey, and Food Investigation stations. The D.S.I.R. makes grants to research workers or to institutions for particular investigations. It provides a number of small research grants for the maintenance of post-graduate students at universities, grants for more senior graduate workers, and grants to assist special investigations.

Grants given by the D.S.I.R.

	1935–6	1936–7	1937–8
Students-in-training	121	121	139
Senior Research Awards	14	14	10
Grants for special investigations	51	59	56
Total number of grants	186	194	205
Total money spent	£26,481	£25,207	£26,327
Average grant per head	£143	£130	£129

The D.S.I.R. is also empowered to assist the formation of co-operative Research Associations to serve the needs of particular industries. These are financed by contributions from the industries concerned, assisted by grants from the D.S.I.R. in proportion to the amounts contributed by the industry.

The Research Associations have been highly profitable to industry and to the country. It was estimated that a single control instrument devised by the Shirley Institute of the Cotton Research Association resulted in an annual saving to the cotton industry of £120,000, i.e. equivalent to the present annual income of the Institute. The British Refractories Research Association, by an improvement in the design of saggers resulting from work costing £8,600 in all, effected an annual saving to the pottery industry of £200,000. Estimates for all research associations are difficult to obtain, but the aggregate saving to industry must represent a return on money invested of between 500 and 2,000 per cent.

It was originally intended that after an initial sum had been spent by the State to get Research Associations started, industry, being then convinced of the value of scientific research, would contribute the entire financial support. For this purpose a £1,000,000 fund was set up by the Government in 1919. When this fund was exhausted it was found necessary to make a different arrangement. At present the State pays an amount equal to that contributed by the industry, above a certain minimum figure for maintenance, and up to a certain maximum. A wide variation in the annual income of a Research Association is thus possible under this system. At present there are about twenty-seven Research Associations representing many sections of British industry, including: Iron and Steel, Non-ferrous Metals, Electrical and Allied Industries, Automobile, Cotton, Wool Industries, Linen, Launderers, Paint, Rubber, Leather Research Associations, and several Associations concerned with the food industries. There is room for expansion, not only in the amount and type of work carried out by the existing Research Associations, but in setting up Associations in some of the important industries not already covered, such as Glass, Brick and Cement and Furniture.

The Department of Scientific and Industrial Research should undertake far more publicity about its work and bring to the attention of industrialists the advantage of investing in scientific research, but it will probably be necessary to take more active steps than mere gentle persuasion and propaganda. Research Associations need a regular source of income so that plans may be made for long-term research work; some means will need to be devised to ensure them an income free from fluctuations. One method which could be adopted is a compulsory levy, either on production or profits, and allocation of a certain amount annually to a fund to be used in making up any deficits in poor years, for special investigations or for capital expenditure. There is every reason why the contributions to the maintenance of Research Associations should not necessarily be confined to the particular industry. For example, it would be of advantage to the electrical industry to encourage research on insulating materials, and to the aircraft industry to encourage research on light alloys and plastics. The D.S.I.R. should be enabled to see that work undertaken at Research Associations is in the interest of the whole industry and is not biased by the particular interests of the larger contributors, who could undertake work on their own immediate problems at their own laboratories. While the practical application of their research results will be of importance to the Research Associations, this process should not be carried to such lengths that they engage in development work proper to individual firms, at the expense of the other firms in the industry and of the State. One Research Association, the British Coal Utilisation Research Association, has taken the step of inviting representatives of the National Union of Mineworkers to sit on its Council. This is a desirable step which could be copied with advantage by other Research Associations.

Industry

Only a part of the research undertaken by industry is carried out in Research Associations. Another type of co-operative research set up without State assistance or the merging of commercial interests, is shown by the Therapeutic Research Corporation of Gt. Britain, formed in 1941 for co-operation in certain fields of research of common interest to the different firms, by Boots Pure Drug Company, British Drug Houses Limited, Glaxo Laboratories Limited, May & Baker Limited, and the Wellcome Research Foundation Limited. The type of scientific work undertaken by industry varies from that of the large complex research organisation of Imperial Chemical Industries to that of small firms, where control and testing is carried out by one or more scientists. Even while participating in a Research Association it will benefit a firm to have its own scientific organisation to deal with immediate problems and development work. In the case of a very small firm (and of the 5,000 firms in the five largest British industries only 126 employ more than

1,000 people) at least one fully qualified scientist could often usefully be employed.

Many industrialists are becoming aware of the desirability of a larger expenditure on scientific research and of employing more scientists, as for example the publication of the Federation of British Industries, *Industry and Research* (1943), and their Conference in March, 1946, on the same subject, have indicated. In the Budget of April, 1944, a scheme for permitting industry to obtain relief from taxation for current research expenditure, in addition to the allowance on capital expenditure permitted previously, was announced. Although this may be expected to encourage scientific research by industry, it might be a dangerous precedent unless steps be taken to see that research results, obtained in effect by the expenditure of public moneys, are made available for general use. Before the war, industry guarded jealously its research programmes and results, and individual scientists were prevented or discouraged from publishing their work in the scientific journals. Some change necessarily took place with the pooling of research for war purposes, although this pooling was not equally extensive in all industries. Industrial firms should not be permitted to return to the pre-war position of industrial secrecy, with consequent overlapping of scientific work and wastage of scientific effort. In this matter the State should take the lead. While the individual firm needs some protection to enable it to exploit its own discoveries, the country as a whole will benefit most from the free interchange of scientific work. No one firm or monopoly association of firms should be permitted to hinder scientific advance by the suppression of research results. While it is not possible to enter here into a discussion of the Patent Law, it may be said that, in the opinion of many scientific and technical workers, much time and scientific effort is wasted in work directed to finding ways of getting round patents, or in hedging round a patent in order to protect one firm against possible competitors.

THE CENTRAL ORGANISATION AND CO-ORDINATION OF SCIENTIFIC RESEARCH

In addition to the departments of the Privy Council described above and the interdepartmental committees between Ministries, several other forms of co-ordinating machinery were set up by the State during the war. In 1940 a Scientific Advisory Committee to the War Cabinet was set up with the then Lord President of the Council, Mr. Attlee, as its president, and with Lord Hankey as its chairman. Its function was to advise the War Cabinet on scientific problems, on the selection of personnel and to bring to the notice of the Government promising new developments. The Minister of Production had three full-time scientific advisers. The Central (Scientific and Technical) Register was responsible under the Ministry of Labour for the allocation of all scientific and technical man-power. The Lord President of the Council, whose department is responsible for the Department of Scientific and Industrial Research, the Medical Research Council and the Agricultural Research Council, as President of the Scientific Advisory Committee was regarded as the minister responsible to the War Cabinet for the general overseeing of scientific organisation.

The suggestions of this book for the post-war organisation of science in this country are based on the need for a body capable of forming a general broad policy for directing scientific research to the problems most important for the country, taking instructions from and reporting to the Cabinet. The need for central co-ordination of our scientific effort is now generally recognised as essential to efficient reconstruction of our national economy. The experience and successes of the war, when the National Government found it necessary to co-ordinate scientific resources, and the election in July 1945 of a Labour Government pledged to reject *laissez-faire* as a national policy, have prepared the way for such a development.

The urgency of adequate co-ordination is particularly emphasised at the present time by:

(*a*) The acute shortage of scientific man-power.
(*b*) The need to establish priorities in the allocation of finance and personnel.
(*c*) The need to ensure the adequate expansion of scientific work in fields at present neglected.

The form of the future organisation must maintain and in fact increase the opportunity of the individual scientific worker, or the team of scientists, to pursue investigations freely, and should give maximum autonomy to all research units to plan their own work within broad terms of reference. At all levels there should be opportunity for scientific workers to take part in the democratic planning of their own work. The future form should combine the minimum of dislocation with the maximum utilisation of the existing structure.

The present Government is committed to a positive policy of national economic development. This requires an equally positive and parallel policy for science. Responsibility for the various sectors of the national economy rests with Ministers and hence, in keeping with present practice, each Minister requires an appropriate scientific organisation within his own department.

These needs can be achieved by an adaptation of the existing system and the addition of a Central Scientific Office at Cabinet level, with further co-ordinating machinery between Government, university and industrial science.* An alternative suggestion for a Ministry of Science, which has been made in certain quarters, should be rejected. If all scientific work were done in a single Ministry, the rest of the Ministries would be divorced from science and the valuable responsibility of Ministers for an essential element of their own work would be lost.

Each Ministry should have its own scientific service suitably strengthened to make it fully effective. This would involve some of the Research Establishments at present responsible to the D.S.I.R., or at least part of their work, being transferred to the appropriate Ministries, e.g. the Board of Trade, Ministries of Fuel and Power, Works, Supply, Transport, Health, etc. The effect of all this on the Government role in science would be:

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* A fuller treatment of these proposals is given in *Science and Government* (A.Sc.W., 15, Half Moon Street, London, W.1, 1946).

(*i*) in the nationalised sections the Government would have direct control.

(*ii*) in the non-nationalised section the Government would have a policy and an interest which would be promoted through advice given directly to industry or through the Research Associations.

It would be possible for the Ministries in this way to carry out positive development work for the benefit of both the nationalised and non-nationalised sectors. Careful thought would be needed to determine how much research to leave under central government direction and how much should be departmental. The general principle might be to leave background research, i.e. research with common interest to several industries, such as that carried out by the National Physical Laboratory or general applied biological work, under central control, but to leave applications and developments with a definite relation to a particular sphere of national economy under the general direction of the individual Ministries.

A Central Scientific Office should be established at the Cabinet Secretariat level as part of the office of the Lord President of the Council. This office should co-ordinate national scientific policy with the economic policy of the Government, and should be linked with other planning agencies in the Cabinet Offices and with the Central Statistical Office. Both administrative and scientific members of the staff would be needed. Some of the scientific members of this Office should be seconded from Ministries, including Supply; others should be specially appointed, e.g. seconded from the universities for a period of years.

The Central Scientific Office, together with other planning agencies in the Cabinet Offices and the Central Statistical Office, would have the function of informing the Cabinet of the progress of scientific work and of the availability of scientific personnel, of suggesting adjustments and new programmes of work, and of arranging for the necessary implementation of plans and the provision of adequate personnel.

Such a Central Office would not be suitable for dealing directly with the great variety of scientific problems that would have to be covered. Some division into subjects would be necessary. There are a number of sciences common to two or more Ministries; thus genetics serves agriculture and medicine, and the social sciences should serve practically all departments. Background research which affects more than one Ministry should be organised under Research Councils. It is suggested that three Research Councils, of the physical sciences, the biological sciences and the social sciences, would be appropriate to cover the field. These councils could grow naturally out of the bodies already existing; thus the present Department of Scientific and Industrial Research (D.S.I.R.) would father the Physical Research Council, and the present Agricultural Research Council (A.R.C.) and the present Medical Research Council (M.R.C.) jointly the Biological Research Council. An entirely new body would have to be formed for the Social Research Council, though this might contain elements from the economics and statistical branches of the Government. Each of these three Councils would need a central administrative and scientific staff and would have responsibility for the various research establishments working under them. They would be Executive Councils receiving an annual grant-in-aid and would have the same constitutional position as the present Medical Research Council.

An Interdepartmental Co-ordinating Committee will be necessary to co-ordinate Government science. It should include senior scientists from each Ministry and the secretaries of the three Scientific Councils, with the Chairman of the Central Scientific Office as Chairman.

International relations in science are becoming increasingly important. To promote this work, an Office of Scientific Relations should be established, responsible to the Lord President of the Council. It should handle official overseas scientific liaison in fundamental and applied science, medical and agricultural science, etc. It should have a special relation with the Foreign, Dominion and Colonial Offices and be advised by a committee of statesmen and scientists specially qualified in matters bearing on scientific relations. This body would also be the appropriate body to be the permanent British Council in the UNESCO organisation when it is set up. In effect this office should form part of the Central Scientific Office.

With the above organisation the country could look forward to a substantial increase in the efficient use of its scientific resources.

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FACILITIES FOR SCIENTIFIC RESEARCH

THE world of science is now such a complicated organisation with so many ramifications that it is necessary to devote particular attention to certain needs of working scientists which are essential for their efficient functioning. The availability of specialised apparatus and equipment, the opportunity for meeting fellow scientific workers and visiting other laboratories, and the efficient dissemination of new scientific knowledge are all vital to the maintenance of maximum progress in scientific research. It is no longer possible to rely on old methods and customs inherited from an earlier age with very different conditions. New thinking, and new organisation of the facilities for scientific research, along the lines discussed below is now imperative.

AIDS TO THE ACCUMULATION OF SCIENTIFIC KNOWLEDGE

The Availability of Special Techniques. In recent years a number of techniques have been developed which are applicable to a great variety of problems in many different fields of fundamental and applied science. But because of the complexity of these techniques they can only be used readily by specialists who have the complex equipment and the necessary training in its use. Money spent in making such aids to research readily available to all who need them is likely to produce a much greater return than an equivalent sum spent on traditional lines. These specialist techniques, which require elaborate costly apparatus, or special technical skill, experience and laboratory organisation, could profitably be used in the investigation of numerous problems but need to be used only infrequently in order to give the required information for any given problem. Such techniques include: X-ray crystallography and related techniques; the electron microscope; the Tiselius electrophoresis apparatus; high-speed centrifuges for particle-weight determination (Svedberg); amino-acid analysis of proteins; mass-spectrography; absorption and other spectrography; the use of "labelled" atoms.

At present some research workers, through personal contacts with specialists using these techniques, can utilise them to some extent; but this has a double disadvantage. The specialists using a given technique may find themselves overwhelmed by requests to examine materials submitted by other workers, and thus be forced to decline or to choose only those materials which fit in with their own research programmes. These specialists could thus become "slaves to the machine," working almost exclusively with materials submitted from elsewhere, and so stultifying their own research work. Or, even if they declined outside work, they might still become "slaves to the machine" by the very fact that the elaborateness of the technique itself necessarily restricted their work along lines conditioned by this technique. Thus the Svedberg centrifuge is of great use in making measurements on macromolecules of diverse organic materials; advances have been made in the knowledge of the composition of biological fluids, such as blood plasma, by its use. But this information is only one type of measurement that needs to be made when studying biological materials of this kind. The same can be said of the other techniques mentioned above. The result is that the staff running the technically-elaborate apparatus tend to concentrate on the kind of study, or the aspect of a problem, which their apparatus can tackle. This is inevitable to some extent, but needs balancing so that a biological problem, for example, is seen as a whole, and collaboration with other specialists, at least in the form of symposia and colloquia, should be arranged.

Central institutes seem to be required which shall be able to specialise in one or more special techniques, and whose work would have two primary aspects: (*i*) research work concerned with the study, development and use of the technique itself; (*ii*) facilities for examination of products or problems submitted by external workers. Aspect (*ii*) would have all degrees of complexity. This could range from relatively simple routine-examinations of materials submitted by research workers from other laboratories, who required only a few measurements to help them with their own problems, to collaborative research on given problems or in given fields. Part of this service can be envisaged as becoming as normal as is the elementary analysis of compounds in organic chemistry, which is conducted by certain laboratories on a commercial basis. These services for examination by special techniques could give not only better and quicker results than if individual workers attempted them (even if they had access to the required apparatus) but the existence of such services would have a much more important general effect. On the one hand, workers would become accustomed to attack their problems from a variety of angles by utilising all appropriate techniques, thus richly enlarging the scope of investigation of particular problems, and at the same time widening their own horizons; and the tempo of research would be increased generally. On the other hand, the specialists concerned with the techniques would have stimulating contact with many and varied fields of research and thus be encouraged to develop and extend their technique, and to introduce new ones, in order to cope with the problems submitted to them. Separate or grouped institutes for the study, development and application of special techniques would be one solution to the problem of making intricate techniques readily available for all research workers.

General Laboratory Equipment and Materials. Much improvement is desirable and possible in the quality, design and standardisation of ordinary laboratory supplies. The keynote to improvement would be more standardisation; already British Standard Specifications exist which cover many laboratory supplies. What is required is that they should be adopted by laboratory suppliers and extended to a further range of articles. An extension of standardisation and rationalisation would lead to a simplification of store-keeping and to easier replacements, with a consequent increase in the speed of doing laboratory work. Work is often held up for quite normal replacements because a required fitting is not available. Catalogues and lists should be of uniform page size, in sectional or loose-leaf form, to facilitate quick reference and classification of like materials or apparatus.

More small mechanical apparatus, e.g. small bench pumps, electric motors for direct drive of shakers, grinders, etc., and centrifuges of all speeds and capacities should be available. The Scientific Instrument Manufacturers Association might give a lead here in attaining standardisations leading to flexibility and interchangeability.

There should be close collaboration between the research and design staffs of the suppliers and the staffs of laboratories. There is a great need for the craftsmen, rather than the salesmen, to make contact with the actual users. This happens to some extent where special or complex apparatus is concerned, but it is with quite ordinary laboratory supplies (at present often shoddy or crude) where this should occur much more systematically. The quality and variety of American laboratory supplies is in general ahead of British products. It would be difficult to support any suggestion for restrictions on the importation of scientific instruments which would tend to favour lowered standards of quality and decreased inventiveness at home.

Mobility of Scientists between Academic, State and Industrial Laboratories. There is a considerable danger that the fields of academic, State and industrial research will become more widely separated from one another than at present. This does not refer to published work but to that which is not published, and to practical acquaintance, by individual scientists, with methods and techniques developed in fields other than their own. Laboratory practice, techniques and methods developed in each of these fields often have special features about which information and practical experience should be freely available. If the optimum value from the funds of knowledge existent in these three fields is to be obtained, some means must be worked out whereby it becomes easy for workers in any one of the three fields to work for a period in any other field. This would have a stimulating effect both on the individual workers and on the different fields, which have a tendency to be conducted in separate environments. Broadly speaking, as discussed elsewhere, in Britain fundamental research is conducted mainly in the academic laboratories, and standardisation and control work, applied research, and some fundamental research, in State laboratories. Industrial laboratories are mainly concerned with the development and application of the results of fundamental research, although their contribution of fundamental research is not inconsiderable. Industrial laboratories in the U.S.A. conduct a greater relative proportion of fundamental research than in Britain.

Research in Industry. The modern growth of whole industries of applied science (e.g. the chemical industry, the biochemical industry) is on such a scale that problems arise which lead to the development of new techniques and methods, or which permit the use of known techniques or methods in new ways or for new purposes. Thus in the industrial field a great body of knowledge and practical experience is being built up which can occur nowhere else, because it is knowledge arising from the very magnitude of operations. This is often so large that qualitatively new features become apparent. Again because of the scale, operations become possible which could not be done on a small scale and which can yield correspondingly valuable chemical, physical and engineering data. Materials and compounds become available in quantities suitable for further research because of the large scale of production, e.g. those occurring in very low concentration in biological materials or as by-products in organic chemical syntheses.

Without this, much fundamental research concerning the structures and functions of biologically important compounds would be almost impossible, and certainly much hampered. For these and other reasons, therefore, the industrial research field provides facilities obtainable nowhere else. Industrial research can draw on all the practice and information deriving from the academic field, because this is all published and access to academic laboratories is freely given. But the reverse process does not function so well because of the maintenance of industrial and business secrecy. This is one of the main hindrances which is met, camouflaged in different ways, in almost every consideration of the optimum conditions for the development of science itself, quite apart from any question of the use of science for the benefit of the community as a whole. There is a danger in that large amounts of scientific knowledge are being acquired and developed in secrecy by private industry, which makes every use of the knowledge freely published in the scientific literature and to the acquisition of which society as a whole has therefore contributed. Yet these bodies of unpublished knowledge existing in industry are owned as private property by private industry; only a small proportion of this knowledge is published. This is bad for the scientists who do the work; they get little or no open acknowledgment of their efforts, are thereby handicapped when they wish to get new posts, and feel frustrated that their work is not published like that of other scientific workers. But the situation is much worse, in the long run, for science itself and for the community. Because not only is the advancement of science impeded by the inability to use all existing knowledge, which only becomes freely available by publication, but it is also extremely wasteful of social energy since much work is repeated unnecessarily. The amount of scientific talent and energy which is wasted in circumventing patents is worth noticing as another example of the way in which a social arrangement (the present patent system) impedes the development of science and its social use.

In addition to the question of publication of the knowledge acquired in industry, it is important that all scientists should be able to gain skill and practical experience in the use of the special techniques and methods developed in industrial practice. Here again industrial science has unique information and experience of great value to other fields of science.

Thus one major problem which must be solved to permit the best utilisation of research in the post-war world is to break down the barriers which separate or tend to separate industrial science from the main body of science. The chief obstacles are those which prevent the dissemination of knowledge and the sharing of practical experience, caused by the existence of privately-owned industry over which the community has little control.

State Research. Excluding that research which must be kept secret for security reasons, research carried out in State laboratories has usually been published, and considerable freedom of intercourse with workers in other fields (academic and industrial) exists, at least in theory. The continuance of this in the future is of great importance for the progress of science, and the tendency since the war to widen the areas of "secret" research needs to be strongly combatted. Heads of laboratories and research directors should encourage their workers to have free contact with scientific workers outside their own laboratories. The factors which lead, in industry, to the treatment of scientific data as private property have not much weight in State research. The main stultifying factors to healthy development appear to be the existence of Civil Service red-tape and a lack of boldness, both in expenditure and in the choice of problems and fields of work. There is a tendency to choose fields of work which industrial research does not exploit because not likely to be immediately profitable, and to avoid fields which industry would rather exploit for itself. The latter aspect may be an important consideration in the choice of problems by Research Associations.

Detailed supervision by the administrative side has a bad effect on the scientific staffs and on the organisation and development of the work. Administration should be designed as part of the organisation to aid the scientific work, not as an end in itself, nor as a set of rules within the rigid framework of which the requirements for scientific development must steer a hampered course. The solution of scientific problems is difficult enough without administrative impediments being superadded.

Academic Research. Research workers in the academic field would often benefit by closer contact with research in the industrial field. Some of the reasons (e.g. access to special skills, methods and techniques) have already been mentioned. Periods of work on special problems in industrial laboratories would undoubtedly help academic workers to lose the ivory tower outlook which many acquire when they remain in the academic field for long. It would also benefit their teaching, since they would have a real acquaintance with the environment and types of problems which will eventually confront many of their students when they take posts in industry. There would also come an internal stimulus to the reform of curricula and syllabuses, since actual experience would show to the academic research worker-teacher, temporarily working in industrial research laboratories, the growing fronts of science as developing there. There should be no under-estimation of the fertilising effect of the industrial research field, and of the avidity with which the most advanced science is often applied and developed in the growing branches of industry. It is too frequently found that the new university graduate has much to learn about special fields of science which have received scant treatment in his university courses, when he begins to work in an industrial laboratory. This is emphasised with the increase in the volume of "private" unpublished knowledge gathered by industrial research. The number of academic posts should be increased so that every worker shall be able to do both research and teaching without the demands on time being so great that one or other side of the work suffers.

The equipment of many academic laboratories needs replacement and expansion to bring it up to the highest modern technological levels. While there will always be a place for those with a penchant for the "string and sealing-wax" type of apparatus, this is no reason for not supplying the best equipment that can be obtained. And the string and sealing-wax complex has always been exaggerated into a myth; the amount of truth in the conception was its emphasis on the development of ingenuity in the experimentalist. This skill can equally well be developed with good apparatus, which can never by itself replace experimental skill.

Besides the conduct of fundamental research and the training of new scientific workers, there is a third important role which academic laboratories could develop more than at present. This is the arrangement of special vacation courses to which workers from industrial and State laboratories could come in order to keep abreast of new work. The questions, problems and points of view brought by these post-graduate students directly from their own fields would also have a stimulating effect on the academic workers conducting the courses.

Facilities for Visiting other Laboratories. These are of the greatest importance in stimulating and refreshing research workers and should not be conceived in terms only of visits to workers engaged on the same or similar problems. On the contrary, the value of this interchange resides more in the intellectual stimulation which results from the discussion of fields of common interest rather than in gaining detailed technical information related to particular problems. Research workers can get stale through the intractability of their problems and through seeing only a limited circle of fellow-workers. This staleness is best dispelled by visits to other laboratories, almost for social purposes; a change from the laboratory to a scientific meeting is not the same. Such visiting is, of course, fairly common in academic laboratories; it is the worker in industrial laboratories who will benefit most by its stimulation and yet who often finds it most difficult to achieve. An understanding of this by the administration and management side of many industrial laboratories often leaves much to be desired.

Research workers in industry often find it difficult to make contact with workers in other industrial laboratories. This applies more to small laboratories than to the larger ones, because in the latter the scientists usually develop enough corporate spirit to make an atmosphere where the scientific work is primary. Over all hangs the administration's fear concerning revelations of "business secrets," and a feeling that their workers are paid to be in their laboratory and not to waste time talking elsewhere. The latter part of the picture may be overdrawn, but the cherishing of "business secrecy" is very real. It is desirable to see established in the practice of industrial laboratories the direct encouragement of interchange visits between working scientists. The risks (if any) to "business secrecy" which might be incurred thereby, would be more than outweighed in the long run by the mental refreshment and stimulation resulting from the contact with other minds and from the break in routine.

International Interchange of Scientists. Personal contacts between the scientists of different countries are of vital importance. What is needed here is a deliberate policy of sending suitable individuals to visit foreign laboratories, not only for special purposes as sometimes occurs now, but with a roving commission to see what is going on in the laboratories and institutes and to come back with first-hand reports of ideas, new techniques, laboratory organisation and practice.

Personal contacts need to be made in four main ways:

(1) by graduates going overseas for further study; (2) by members of the staffs of research departments and universities proceeding for further study; (3) by scientists on loan or exchange from overseas institutes; and (4) by visits by specialists or administrative officers to survey their own particular field.

Much attention was given to this matter at the Royal Society Empire Scientific Conference held in London in 1946 and the need was shown for:

"(*a*) Adequate provision by universities and research institutions to enable the senior and junior scientific staffs to take periodical leave for overseas visits, both short and long term;

(*b*) The raising of staff complements to a level sufficient to afford individuals adequate time for research and for study or for special leave without thereby placing additional burdens on their colleagues;

(*c*) Provision of the largest practicable number of travelling scholarships for post-graduate work;

(*d*) A system of adequate financial provision for travelling and subsistence allowances to avoid loss to the individual due to differences in living costs in different countries; this is to apply both for members of university staffs and for holders of travelling scholarships;

(*e*) The provision of resources to enable the invitation of scientists from overseas for short periods to advise or for collaboration in specific research projects:

(*f*) The exemption of all travelling scholarships and allowances from income tax either in the country of origin or of reception."

The Conference also recommended an official policy for the continuance and development of a system of Commonwealth Liaison Offices. This was regarded as an essential part of the machinery for facilitating the interchange of scientists and related activities.

The United Nations Educational Scientific and Cultural Organisation (UNESCO) is also well aware of this need and can be expected to make special efforts to arrange for an interchange of scientists between the main centres of scientific work in the world and the outlying regions where special difficulties of scientific isolation exist.

The need for such contacts has been vividly shown by the way scientists from all countries have availed themselves of the Society for Visiting Scientists (set up in London during the war under the auspices of the British Council). It is essential that whole-hearted support be given to the facilities which UNESCO and other bodies can make available. There must be a willingness on the part of controllers of laboratories to take part in and to encourage this interchange. To do it, administrators and directors should pay careful attention to requests for such visits made to them by their own scientists and should provide the necessary facilities and finance. The expenditure will be well repaid by the stimulation and fertilisation of the minds of the scientists who make such visits, apart from special technical information they might also acquire.

The Unity of Science as a Social Activity. Implicit in the previous paragraphs is the idea that science is a unity, a great lake of knowledge fed by rivers flowing from many sources. The volume and character of the streams of knowledge may vary with their sources and the regions they traverse, but the contributions of all are needed to characterise the sum total of knowledge. There is therefore no real reason for the development of a certain snobbery which tends to look upon fundamental research as something of higher moral quality than applied research.

The intricacy of the problems of applied research is in no way less than that of those of fundamental research, and the personal qualities required of the workers who seek to use, apply and develop scientific knowledge are the same as those of the fundamental research worker. The worker in applied research is just as necessary as and performs work of equal social importance to that done by the fundamental research worker; their functions are complementary. It is through the labours of the scientists who apply fundamental knowledge that this knowledge comes to fruition. The technical problems which have to be solved in bringing this about are different from those involved in the initial discoveries, but only specifically different; not different in degree of complexity, or in anything measurable in terms of the personal qualities needed to solve them. The technical worker engaged in translating scientific knowledge into practical application has to solve, besides the directly technical questions of materials, methods and apparatus, the much less easily defined problems of organisation which arise when large-scale continuous production is undertaken. The foregoing is designed to emphasise that the differentiation of groups of scientific workers who tend to become popularly classified into a hierarchy, with the fundamental ("pure") research worker at the top, in fact only arises out of the division of labour and the segregation of the greater proportion of fundamental research in the universities, in Britain. The labours of all are equally necessary to the maintenance of men's control of their environment and to men's understanding and therefore mastery of Nature.

Scientific Societies. As science has grown and special fields of science have become differentiated, specialist societies have come into being to bring together the workers in the particular fields. These scientific societies usually have two main functions : (*a*) to hold scientific meetings at which original research work is communicated orally and can be discussed; (*b*) to publish a journal containing the results of original research. Membership of a society usually carries with it the right to receive the journal and the membership fee is correspondingly high. Many scientists would wish to belong to more than one society in order to have the benefit of their meetings. If the subscriptions to societies did not include the price of journals, they could be proportionately lower and thus facilitate membership of more than one society. The same result could be achieved by "all-in" subscriptions covering, in effect, membership of a group of societies. The obstacles to such an arrangement are chiefly financial, for it would be easy to preserve the individual characters of different societies, which otherwise differ mainly in the services (e.g. library) which they render to their members. The process of making easier membership of several scientific societies by the reduction of subscriptions which would result from a separation of membership and journal subscriptions would greatly help individuals to broaden their interests and to counteract the all too easy tendency to narrow specialisation. Coupled with this proposal are those concerning the publication of scientific journals discussed in the next section (p. 193). This broadening of interest could also be fostered by joint meetings bringing together scientists of different but related fields. This happened to an increasing extent during the war and should be extended.

THE DISSEMINATION AND AVAILABILITY OF SCIENTIFIC KNOWLEDGE

The Problem. The vast volume of scientific publication, which is increasing in rate of output, makes it very difficult for individual scientists to be cognisant of the whole literature in their particular fields of work. Everything should be done so that access to the literature of science is made easier. The speed of future scientific advance will be materially accelerated or retarded to the extent that we succeed or fail in building up an efficient world organisation for the dissemination of information between scientists.

At the present time the startling fact is that there are more than 40,000 scientific journals in the world, and their number is growing. No country has attempted to assemble or to make a systematic review of more than a small fraction of these publications. Dr. S. C. Bradford, the President of the British Society for International Bibliography, has stated* that in a selected grade of 15,000 of these journals an average of three-quarters of a million individual scientific contributions appeared each year, and that only one-third of those contributions were referred to in any one of the 300 leading journals providing abstracts or indexes. It is important to study this position in somewhat more detail and then consider positive proposals for improvement that are being made.

Rationalisation in the Publication of Scientific Journals. Most scientific societies publish journals which are the chief medium by which original research becomes part of culture and available for social use. Some other scientific journals are published, not by societies but by groups of individuals, possibly with commercial backing, to cater for more or less well-defined fields of scientific research. The appearance of new scientific societies and journals to correspond with the growth of new fields of science shows a marked time-lag. There is a tendency for the older societies to look upon new fields as applied branches of the older fields, rather than as something qualitatively new. This gives rise to a situation where papers dealing with a given field may eventually be published in a number of different journals (corresponding, for example, to the societies to which the authors belong), rather than in one journal the main focus of which is the subject or field in question. Thus the Journal of the Chemical Society has come, with the years, to be primarily a journal of organic chemistry, and various more recently developed fields (e.g. physical chemistry, electrochemistry, biochemistry) have their appropriate societies and journals. But this does not prevent the Journal of the Chemical Society publishing papers in these fields when they are submitted to it by its members; other similar examples could be given. This situation arises in part from the time-lag between the differentiation of a new field and its acquisition of a recognised status, and the organisation of appropriate societies or journals to reflect this new field. The result is that a worker in the new field, often a border area between fields of mature status, has to comb a wide variety of journals in order to become acquainted with the relevant papers on his subject. This is wasteful of time and energy, is inefficient, and prevents the worker from reading round his own subject in a rational way; his general background reading is thus necessarily haphazard.

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* At the Royal Society Empire Scientific Conference, June–July, 1946.

It is a feature of the development of science that it is difficult at any one time to foresee what the future requirements as to societies and journals are likely to be, yet there is an organic growth of new fields out of those which have preceded them. The body of scientific knowledge is a growing thing; every field is connected organically with every other. Thus in order that scientific periodical publications should reflect rationally the different fields of science in a given period, the scope of papers published by given journals should be variable in conformity with the development of scientific fields. At present this is not the case, or is the case only to the extent that new societies and new journals at last appear, often after a hampering time-lag, and when a field has grown to relative maturity. Yet it is precisely when new fields of science are developing that the task of reading the literature and of finding a suitable journal in which to publish is most difficult. It would be a great convenience to scientific workers if a greater sorting of papers before publication took place so that, within reasonable limits, a given journal would contain papers dealing only with a given field. This is not a plea for rigidity and for abetting narrow specialisation. On the contrary if, within limits, any given journal were more or less homogeneous in fields treated, then, given a rational organisation of scientific journals to cover all fields of science, it would not only be much easier for the specialist to find the papers he wanted and the right journal to publish in, but it would also be much easier for him to organise his general reading, his browsing. The economy of effort would be very great. Some editorial boards at present do make a practice of recommending to authors that certain of their papers would more appropriately appear in journals other than those to which they were first submitted. This practice alone, if consistently adopted by *all* editorial boards, would result in greater homogeneity and the benefits outlined above.

Besides the great economy of effort which would result from this sorting of papers into appropriate and homogeneous journals, there are other aspects of scientific periodical publishing of importance to the working scientist. These include questions of personal subscriptions to societies and journals. If some scheme were adopted whereby the subscription to a scientific society were separated from the subscription to the society's journal, and this were coupled with a general system of buying off-prints of papers, solid advantages to the individual scientist and useful possibilities of organisation for the benefit of scientific advance would ensue.

The Availability of Separate Copies of Scientific Papers. The personal possession of complete journals is often not required by the individual scientific worker, unless he be totally isolated from adequate library facilities. What is much more important to the individual scientist is to be able to collect off-prints (separates) of particular papers which he wishes to study and to file for reference. These off-prints will not only be derived from the journal or journals to which he may be a subscriber, but from any journal. At present the collection of off-prints is by request to the *author*, who meets the expense of getting them from the printer, unless his firm or institute pays for them. Thus the request for an off-print may or may not be successful, depending on the number the author may have available; and because the *author* bears the burden of cost, many people are diffident in asking.

Abstract Journals. It is difficult to overemphasise the importance of Abstract Journals. Comprehensive and efficient abstract journals are essential in order to keep abreast of new work. It cannot be said that the existing abstract journals are adequate except possibly in the field of chemistry (in the broadest sense), where the Chemical Abstracts of the American Chemical Society is outstanding and covers a very wide field. With this exception, abstract journals in English are not adequate. Since the English language is common to the U.S.A. and to large areas of the British Empire, and is read by many scientists who do not speak English, it would be an economy of effort if only one series of abstract journals were to appear in English. This is primarily a question of arrangement between the appropriate bodies in the U.S.A. and Britain, and appears to be a desirable objective. But even apart from this it is clear that if abstract journals are to be published in Britain very serious efforts should be made to organise a comprehensive and efficient service. A bold initiative is required to secure adequate finance to run an efficient and comprehensive abstracting service, otherwise the much needed improvements may be indefinitely delayed. This initiative should come from the State, through the provision of funds which would allow an adequate staff and organisation to run a first-class abstracts service.

To cut the knot of conflicting interests which at present impedes the development of good and comprehensive British abstract journals, and to get early and satisfactory action, it would appear necessary that the task should be undertaken by the State and organised through the proposed Central Scientific Office (p. 176) or at least that a broad representative committee should receive an adequate State subsidy for the purpose. This is not to say that the organisation of the Abstracts Service should be the concern of a State Department. What is required is adequate finance to enable the scientific bodies who are already concerned with abstracting services, no longer to have to make their plans fit limited sectional budgets and sectional interests. The whole problem needs lifting out of the present tangle of conflicting interests by the provision of adequate finance from the State. Then the planning and organisation of a good Abstracts Service could be dealt with in terms only of the provision of the best service to meet the admitted need.

A Scientific Information Service. At the Royal Society Empire Scientific Conference held in 1946 the case was strongly made that it was now time to remodel certain features of the publications services so as to provide the workers in science with the maximum of information relevant to their work and the minimum of irrelevant information. There was much support for the view that the individual paper was the basic unit of scientific information and that it was necessary to reorganise its production and distribution. In a statement, Prof. J. D. Bernal, F.R.S., said:

> "The distribution of individual papers and abstracts could be undertaken by a number of central distributing offices, set up jointly by scientific societies and other publishing bodies in each country. The individual paper would be sent in, accepted and edited by the scientific society as is done at present, but it would be printed and distributed by the central office to individual members of societies in its own country and to corresponding distributing centres in other countries. Each member of the society would receive a number of papers, at least as large a number as he now obtains for his regular subscription, but these papers could either be obtained by a standing block order for papers in certain defined fields, or by specific request or both. Extra papers such as would be needed by libraries or institutions, would be available on higher rates of subscription. The individuality of journals would be retained, as papers published by a particular society could always be bound in volumes as at present, but scientists or libraries would be much freer in the arrangement of material. A similar scheme could be adapted for reprints and reports."

After their discussions, the Scientific Information Services Committee of the Royal Society Conference made the following special recommendations:

(1) Consideration should be given to the establishment of a network of information services throughout the Dominions. Such a network would provide central focal points and for a two-way transmission of matter (either direct or through existing local centres adapted for the purpose).

(2) In view of the need of the scientist for possession of individual scientific papers on his own subject, the

possibility of the publication, classification and distribution of papers in separate form or as reprints should be considered.

(3) The issue of occasional reviews of special branches of science, both for the specialist and for the general scientific reader, is considered desirable as a supplement to other forms of publication.

(4) The extended provision of micro-film and other forms of documentary reproduction is considered important for the rapid transfer of information throughout the Commonwealth. An economic service for the purpose requires centres in the United Kingdom and in each of the Dominions.

(5) The conference recognises that the qualifications of staff in scientific information services and special libraries call for special training and selection, and recommends the provision of facilities for increasing the number of properly trained staff.

The importance of such a scientific information service has also been recognised by UNESCO, and consideration has been given to the special contributions that can be made by such an international body. Proposals have been made for the setting up of a World Bibliographical and Library Centre, which among other activities would be responsible for the formation of and participation in abstracting services, and for encouraging research into all questions of documentary reproduction technique and development. It is possible that UNESCO will provide machinery to assist Governments, libraries and institutions to establish better methods for the exchange of publications.

The Natural Sciences Committee of UNESCO is also proposing that there should be a study made of the rationalisation of the present system of publication of scientific journals, including abstracting and reviewing services, and suggest that UNESCO might undertake a certain amount of abstracting and reviewing of journals in fields not adequately covered by an existing organisation.

A SCIENCE PUBLISHING ORGANISATION IN BRITAIN

It is obviously necessary that there should be set up in Britain an organisation which would be, in effect, a British scientific journals and abstracts publishing organisation. This body would be one of the central distributing offices of a world network, and would be directly in touch with UNESCO.

It would have the main objectives of rationalising the publication of scientific papers so that relatively homogeneous journals should appear, sectionalised to cover rationally the whole field of science, and of organising efficient and comprehensive Abstract Journals. A second major objective would be to take every opportunity which this co-ordinated organisation would render possible, to improve all technical aspects of the actual printing and publishing, e.g. standardisation of page-size (a convenience in filing off-prints); securing optimum legibility (type-faces, page lay-out, page size, etc.); standardisation of indexing.

The editing and production of scientific journals falls into two sections: (*a*) the scientific editing; (*b*) the technical processes of production in print and the business side of publication.

(*a*) *The Scientific Editing.* The best editorial boards for the proposed sectional journals would clearly be those elected from the membership of the appropriate societies or groups of scientists whose interests are served by the corresponding journals. This is what usually happens now. The editorial boards would thus be elected by those best qualified to judge their scientific abilities and fitness for editorial responsibility; in this way individual scientists would feel confidence in the editorial boards they elected or appointed through the committees of their own societies. The chief function of the scientific editorial board would be: the assessment of papers submitted for publication and their preparation for press, with the redirection of papers to more appropriate journals where necessary; the formulation and control of the policy of the journal as regards scientific content and field covered; the maintenance of the requisite liaison with other editorial boards so that the fields covered by the various journals should overlap as little as possible.

(*b*) *The Technical and Business side of Publication.* The whole of the administrative, printing, distribution, advertisement, etc., side of the publishing could be run by centralised professional staffs. Here an enormous economy of effort could be achieved, since one staff could conduct the technical and business affairs of many journals. This would render unnecessary the large amount of time which the usually unpaid scientific editors have to devote to these matters, and would avoid the overlapping of much of the work when it is distributed, as now, among many different printer-publishers. The same professional staff could also supply the secretarial assistance which the editorial boards need for the conduct of their work. The degree to which this centralised organisation would replace existing publishers would depend on a variety of factors, but even if the publishing were still continued largely on the present basis, there is a very large amount of administrative work which the scientific editors do at present which could well be removed from their shoulders. The proposed central organisation could arrange rationalisation and organisation for the benefit of scientific advance and for the convenience and service of scientists, even if the present printers and publishers were still used. There is relatively little competition between different journals, from the commercial point of view; it is more a question of relatively steady sales.

(*c*) *Comptes Rendus.* Side by side with the journals containing the complete scientific papers should be published simultaneously a corresponding series of "comptes rendus," i.e. long abstracts of the papers published in the journals proper, but giving only the essence of their findings, without experimental details, protocols or discussions. The centralised publishing organisation would also be responsible for the Abstract Journals proper, probably sectionalised, which should appear every two weeks.

It is proposed that it should be made possible for individuals to subscribe to as many journals, *comptes rendus,* and sections of the Abstract Journal as desired. Probably many individuals would not wish to subscribe to more than one Journal, but to several *comptes rendus* and sections of the Abstract Journal (printed on one side of the paper and possibly perforated to assist in filing). Libraries would wish to subscribe to a wide range of complete journals, the corresponding *comptes rendus* and the Abstract Journals.

(*d*) *Off-prints* (*separates*). A further very important service could be conducted by the central publishing organisation, namely the supply of off-prints and/or photostat copies of individual papers by sale to those requesting them. The price of all publications could be kept at a level which made the enterprise pay its way, with a margin for starting new journals, and yet, through co-operative effort and economies effected by central organisation, be lower than at present.

Rationalised Science Publishing. It is clear that this scheme or an analogous one would be capable of eliminating many of the defects which at present make the dissemination of scientific knowledge much less effective than it might be.* Many scientists would no doubt agree with, and add to, the catalogue of defects mentioned here, both from a personal and from a general point of view. As sketched, the scheme will no doubt seem Utopian, for a host of reasons, including traditional and sectional loyalties, natural pride of societies in "their own" journals, and the more fundamental reasons of finance; all this is admitted. But the problem is so urgent and is rapidly becoming worse, that drastic co-operative measures are needed to solve it.

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* See N. W. Pirie: "Draft plan for the publication of Scientific Papers" (1945. *J. Documentation,* I, 26).

If the financial upheaval and reconstruction which would be needed to float the central scientific journal organisation could be overcome, there is little doubt that within a few years the organisation would pay its way. A sufficiently large State grant should be made available to float and foster the organisation during its formative years. The problem is too big to be solved piecemeal, and although there is a general ferment in the scientific world concerning the problems of scientific publication, with the best will in the world these are not likely to be solved adequately without a large sum of money to start the required organisation. It would be to the interest of the community that this renaissance in scientific periodical publication should take place, and every citizen should urge that the State gives the required assistance. The learned societies could rapidly appoint a broad representative committee to carry out the task once solid financial backing were assured.

16

SCIENCE AS PART OF CULTURE

The Cultural Value of Science. Earlier chapters have been concerned with the direct effects of applied science on the community, in developing industry, improving health and living standards, and in decreasing human suffering and drudgery. But there are other less tangible ways in which science can contribute to human welfare. Obviously any developments which improve man's material well-being bring with them possibilities of greater enjoyment of life and more opportunities for recreation and leisure. Since the middle of the last century the length of the working day has been reduced from sixteen or fourteen hours to eight or nine hours at present. A future society can certainly be envisaged in which the length of the working day is progressively decreased as a rising level of technique makes the production of the material requirements of society possible with less and less human labour. From the scientific standpoint this seems the logical development, since the potential wealth of any society is determined by its ability to produce the commodities required by its members. But in an unplanned society a technological advance may, by enabling one man to do work formerly requiring twenty men, throw many of the other nineteen out of work, if no steps be taken to make use of their labour-power. To make full use of the potentialities of science for the benefit of all men a degree of national and international planning is needed which will enable the required goods and services to be produced, while offering to each man and woman opportunities for work. A democratic citizenship alive to the potentialities of science is also needed. In the modern world the man in the street should become a scientifically-minded citizen; firstly, in order to understand his role in modern industry, the way in which the world is changing, and to be able to exercise his democratic rights on the basis of knowledge instead of prejudice; secondly, because of the general cultural value of such understanding to him as an individual. The story of science is one of the most enthralling of all stories, the story of incessant struggles of men against the unknown, in which, stage by stage, overcoming difficulty after difficulty, men are always the victors. Every discovery in science, however small, all positive knowledge, is a gain for mankind whether or not it may prove later to have direct material application. An appreciation of this implies a new attitude and understanding both by scientists and by the public. A broader and more general education in science for everyone appears to be needed, not so much a training in special branches of science as an understanding of the scientific basis of things of common experience such as food, health, heredity, genetics, and an appreciation of the value of factual data and the experimental method.

It is important to point out the fallacy in the common contradistinction made between science and culture. There is often an implication that the culture of a society is its literature, music and art while its science, in so far as it has any value other than to scientists themselves, is merely a utilitarian asset. To scientists the pursuit of science has an intellectual and æsthetic value which may be compared with that given by the cultivation of the graphic arts or music; but it is certainly not generally conceded that such appreciation can be shared by others in a similar way. Both the present educational system and the attitude of some scientists are to blame for this. An improvement in popular education in science should be reinforced by a conscious effort on the part of more scientists to explain their work in popular terms.

In this age no man can be considered to be cultured who makes no serious attempt to understand and appreciate the broad principles of science. Although there are some scientists who have no interests outside their own field of study, it is common to find that scientists in general have a wide range of interest in human affairs and the arts. But few of the so-called cultured intelligentsia have the faintest inkling of either the history of science or of scientific theories; that is to say, they are cut off from at least one half of the real culture of the modern world. This is not to suggest that an interest in science is a superior attribute to an interest in the arts, but that a society's heritage and contemporary progress in science is as integral a part of that society's culture as is its music and literature, and should be absorbed normally as part of general education. This was achieved during the Italian Renaissance, when a mighty flowering of art and literature was accompanied by an intense and eventually scientific interest in man and nature. Leonardo da Vinci represents perhaps the pinnacle, the most fully developed man, interested in every aspect of culture. But that period was noteworthy for many other outstanding men who were almost equally many-sided. This was no chance phenomenon, but the emergence of these widely cultured men reflected the *general* social environment which favoured the all-round exploration of man and the world around him. The aim of education should be to inculcate an appreciation of the broad principles of science and scientific method throughout the community. This should lead to a recognition of science as a precious possession of the community, and not as an esoteric marvel to be admired or feared without understanding. This proper broadening of education would shatter the attempts of reactionary people to suggest that it is "science" which is responsible for wars and economic crises, as a smoke-screen to hide the real social causes.

Educational Classes. The basis for developing an appreciation of science as a part of culture is primarily a reformed educational system (see Chapter 17). But however excellent school-training may be in this respect, it should be only the first stage. Many people (apart from those training for a scientific career) will wish to attend further educational classes in their spare time. For these the excellent work carried out by such organisations as the Workers' Educational Association, the National Council of Labour Colleges, the extra-mural boards of universities, and many voluntary organisations, is invaluable. More scientific organisations or institutions could co-operate in arranging and running classes of this sort, particularly in the smaller towns. This work would be more valuable if bigger grants were given by the State or by local authorities for demonstration lectures and simple practical work. Where it has been possible to arrange for practical work the enthusiasm of the class has usually been well worth the extra preparation entailed.

Exhibitions and Museums. These are potent educational instruments, not only for science. During the war years there have been a number of major exhibitions, such as the "Army Exhibition" which gave a vivid impression of army equipment and organisation, the "Fuel Saving" Exhibition, and a large number of small travelling exhibitions, suitable for circulating to small units. Such exhibitions, small and large, can be a very useful way of demonstrating and explaining scientific subjects. Two recent exhibitions by the Association of Scientific Workers on "Scientific Photography" and "The Chemical Industry" were put together by groups of scientists, and had the aim of showing a particular application of science to the public.

Museums, with more permanent exhibits, can present a subject in a more detailed and fundamental manner, and can be interesting and stimulating if they adopt the right approach; they can also be the centre of local activities, such as science clubs, discussion groups and courses in science. The usual and more obvious approach in museum exhibits is to illustrate the facts and principles of the physical sciences and natural history; but it is also very valuable to illustrate the scientific background to life in general. This has successfully been done, for example, by special exhibitions in the National Museum of Wales. There each exhibition occupied the whole of a large gallery for periods up to a year. The subjects dealt with have included: Maps, their history and uses; Aspects of forestry in Wales; The fisheries of Wales; Coal in science and industry; Plants in the service of man; Tin through the ages, in arts, crafts and industry; Fuel and making the most of it. In such exhibitions arts and crafts, geography and history, archæology and industry, science and engineering are shown to be different expressions of one great theme—human progress. The exhibitions show the part which science plays in everyday life, what is owed to those who work out the scientific and technical details which lie behind the manufacture of even the most commonplace of articles and materials. They show how the industries of one country are dependent upon the raw materials of another, and they illustrate the methods adopted at various times and in different regions to deal with the problems of production, transport and manufacture. In short, they provide a background of general knowledge of the real world against which the visitor can set his own personal experience, and by reason of which he can better appreciate the significance of current topics and trends.

Films. The 19th century taught that a work of art is the product of a secret, mysterious and personal inspiration, and that it is a decorative addition in life, outside the sordid economic technical business of living. So it was that Victorian culture had no place for economics and mechanics. For art went out of the window as soon as a job of real work came in at the door. This philosophy still lingers on, but the film is helping to explode it. Films are the products of co-operation, and cannot be made except by what can be called "inspired co-operation" and by using mechanical, optical, chemical and electrical instruments. For this reason, of all art forms, the film is the one which has special affinity for the scientist, and fits easily into his way of thinking and working.

The film is an art-form peculiar to our time. Unlike many of the art-forms from which it is derived, it is something essentially for the many. The tools with which it is made have been designed and built by scientists, and the men who make films must be artist-scientists, capable of using precision equipment. The film is the scientist's own artistic medium, which he must learn to use and to command. (*Citizen Kane* was made as much by the man who developed coated lenses, making possible a great depth of focus, as by Orson Welles.)

The film, too, has given exposition an æsthetic quality of its own, and has made it into an art, as Faraday did a hundred years ago when he wrote *The Chemical History of a Candle*. The films *Airscrew* and *Mouvements vibratoires* derive their memorable effects of lucid exposition from the innate qualities of the film as an art-form, including composition in space and time, tempo, visual analogy, contrast and comparison and the integration of images. This new æsthetic of exposition makes the film of great significance in interpreting science to the citizen. The astonishing growth of scientific film societies proves this, and shows that tens of thousands of citizens are determined to learn about science. Already the scientific film societies are more numerous than the æsthetic film societies were even at their heyday. Indeed, it is significant that the ordinary film societies closed down at the beginning of the war, at a time when the London Scientific Film Society and the Aberdeen Scientific Film Club—(the first two in Britain) started their programmes.

The scientific film society movement alone is not enough; if the maximum cultural benefit is to be attained from scientific films they must secure a proportion of time on the public screens. Scientists and interested non-scientists should form audience clubs in every town to criticise local programmes and to persuade local exhibitors to book the kind of films they want to see. If they cannot get what they want, they should organise their own public showings of 16 mm. films. Such groups should also study the local exhibitor's problems and help to solve them. The Scientific Film Association will send out particulars of good scientific films which are available for booking, e.g. the Graded List of Films; no exhibitor can help it if he cannot find films. By constructive criticism, by personal contact with the local film trade, by personal contact with managers and projectionists through their union (The National Association of Theatrical and Kinematograph Employees—N.A.T.K.E.), much could be done. Even uncoördinated public criticism has on occasion compelled cinema exhibitors to protest to the Newsreel Association at the attitude taken by the newsreels on certain socio-political matters. How much could not organised criticism achieve to secure the showing of more scientific films?

The Press. Newspapers and radio programmes play a very large part in informing the public about current affairs and in helping to form public opinion. Yet the space in newspapers and the time in radio programmes allocated to scientific topics appears to be inadequate to fulfil the real need. Newspaper reports on scientific discoveries too often take the form of sensational stories, often highly inaccurate factually. This is due in part to the policy of leaving feature writers, who themselves have no special scientific knowledge, to write up a highly-coloured story. Also, scientists may be criticised for a certain unwillingness to discuss their own work or an inability to make explanations in simple terms. The main reason for this has been that too often in the past cautious answers to questions in an interview have been made to appear "sensational," even when they have not been recorded incorrectly or with the wrong emphasis. Many outstanding figures in the history of science have been capable of clear and simple exposition. It is time that all national daily newspapers should employ at least one fully-trained scientist who could handle their scientific stories and be responsible for accuracy and correct emphasis in presentation. At present only a few national newspapers employ regular scientific correspondents and reach a high standard in the presentation of scientific news. In addition to employing scientific correspondents who are responsible for feature articles, it should be as normal to employ a full-time member of the newspaper staff who is a scientist to vet the presentation of all scientific press-items, as it is to employ a sports editor. There is also room in the Press for occasional articles contributed by scientists both on their own subjects and on the more general problems of science and society. This is not unknown to-day, but far more could be done when larger allocations of paper become available. The subject is of sufficient importance and interest for it to be unnecessary to restrict contributors to the relatively few well-known men of science. Science is surely worthy of space comparable to that devoted to sport and crime in the national Press.

Radio. Broadcasting offers an excellent means of reaching a wide and attentive audience; programmes can be regular or special features. With a clear and imaginative policy it should be possible to build up a regular listening public for science in the same way that the B.B.C. has helped to build up the popular audience for first-class music. During 1944 the time devoted to science on Home and Forces programmes was approximately half an hour out of the week's broadcasting. This can be compared with 6–7 hours devoted to religion, 10–12 hours for other than scientific talks and the 60 or so hours for the various types of music. On the other hand, overseas programmes have contained many excellent series of scientific talks and the standard of science broadcasting in the schools programmes is very high. During 1945 scientific broadcasts improved somewhat in quality and in quantity. Such features as "Yellow Jack," the story of work on yellow fever, show what can be done to present an interesting story of research in a manner both accurate and entertaining. Discussions between scientists and non-scientists on various topics have presented different view-points to the listeners, but have suffered from a lack of complete clarity on the points under discussion, so that conclusions were seldom drawn and the subject was left in a more or less confused state. It appears reasonable to suggest that there should be an authoritative person in the B.B.C. of high scientific standing, responsible for all science broadcasting, who could be in touch with the various scientific organisations. The time given to science should be increased to several hours a week, with talks, debates, and special features. Talks might embrace the following four categories:

(*i*) The history of science; scientific discovery and development; the lives of scientific workers; the progress of science and how it has affected, is affecting and could affect ordinary life.

(*ii*) Talks designed to explain the scientific basis of natural phenomena.

(*iii*) Applied science—Industry, Housing, Agriculture and Food, Medicine and Health, Education and Social Habits.

(*iv*) A regular commentary on the scientific aspects of current events; reports on scientific discoveries; reviews of scientific books; notes on congresses and individuals.

The series "Your questions answered" has had some very good answers to scientific questions. "Science Survey," replacing the earlier "Science Magazine," is both lively and informative and is a welcome addition.

It should be possible to organise listeners' groups for science, as for other topics. If a regular time were allocated in the programme for the groups they could be encouraged to undertake natural history surveys and conduct simple experiments as well as to discuss the scientific talks themselves. It should also be possible to have a radio scientist, analogous to the Radio Doctor and the late Mr. Middleton, who could give short talks regularly. Although listeners to scientific programmes must be considered as a small minority group at present, and no figures are available on how many listeners would welcome this policy, there is every reason for attempting, through broadcasting, to present more science to the public and for experimenting in programmes until the listener response shows that the right method has been found.

Co-ordination. One of the chief difficulties encountered in the endeavour to spread scientific knowledge is the lack of any central clearing-house for information. This is perhaps most acutely felt with radio and the Press when up-to-date reliable information is required rapidly. The method of personal contacts has become slow and cumbersome with the complexities of modern knowledge. Some form of organisation seems needed to bring together the results of scientific research in a form readily accessible to different persons and organisations requiring it. The British Association for the Advancement of Science has over a hundred years of continuous activity in making the facts of science more generally known, and during the Royal Empire Scientific Conference in 1946, it called a conference of scientific bodies to discuss: "The dissemination of scientific information to the general public." The report presented to the conference by a working-party suggested that an Institute of Scientific Information should be set up under the ægis of the British Association. This Institute would keep records of research in progress, of scientists able to give information on special topics, release authoritative scientific news to the Press and B.B.C., and assist with exhibitions, films and all forms of publicity for science. This proposal is worthy of very serious consideration.

Internationally, UNESCO, besides fostering the interchange of knowledge among scientists, should be able to give much assistance in this more general field. Firstly, in formal education, interchange of experience in methods of teaching and subjects taught, and assistance to the more backward countries with apparatus, books and teachers; secondly, the interchange of materials, particularly films and exhibitions where little language difficulty is encountered; thirdly, the interchange of ideas and methods of making science known to the public.

17

SCIENCE IN GENERAL EDUCATION

ONE important purpose in education is to fit people for life in the environment in which they are going to live. It is essential therefore that, as suggested in the previous chapter (Chapter 16), the teaching of science should be an important part of the general educational system, for the environment is to an increasing extent technical and scientific and controlled by man. Those with some knowledge of scientific principles can best fit into it. To a large extent the present educational system in Britain is a relic of a classical tradition designed to fit gentlemen for a life in which they had no concern with the mechanical arts. Something different is needed for the present-day environment. Again, some knowledge of science and its history is needed in order to understand man's historical progress, and present-day cultural and philosophical outlooks.

Not only is the amount of science teaching for the non-specialist scientist at present inadequate but what is taught is often ill-chosen. An attempt is generally made to enunciate laws, to carry out a few experiments purporting to demonstrate the validity of these laws and then cursorily to describe a few relevant phenomena from everyday life. This approach may possibly be correct when those who intend to specialise in science are being taught, but the opposite approach, from the particular to the general, is better when science is being taught as part of a general education. At every stage a phenomenon or device with which the pupils are familiar should be studied and an attempt made to understand the principles involved. From these principles, at a later stage, the systematisations that for convenience are called "laws" will be derived.

The method of education is no less important than its content, and there is room here for research into methods of teaching all subjects. During the war physiologists, doctors and psychologists collaborated to study the best methods of presenting information visually. This work was done for the Services when men from all walks of life were being taught specialist subjects in as rapid a manner as possible, but many of the results of these studies should be of value in considering school teaching methods. Departments devoted to the study of visual education, such as exists at Exeter, and departments of universities and training colleges devoted to the scientific study of educational methods generally, should be inaugurated.

The Aim in Science Teaching. Before considering what scientific subjects should be taught, it is necessary to decide the main contributions which science should make to a general education. Firstly, it is important to inculcate an appreciation of the scientific method of observation and the analytical study of facts in testing hypotheses. This would involve teaching children to observe carefully, to record their observations systematically and faithfully, and to accept the principle that no prejudice or personal opinion should weigh against their factual observations. They should be taught to regard the world as a whole, and to look upon the history of man as a progress in understanding and control of nature in which they can share. Every encouragement should be given at all stages to that curiosity with which people, especially when young, are naturally endowed. The organisation of surveys or simple research, either by individuals or groups, can combine the satisfaction of this curiosity with much instruction. The pupils should be taught to carry the method of scientific observation and thought into all aspects of their daily lives.

Secondly, children should learn how scientific and technical discoveries have made possible economic and social advances. The prehistory and early history of man can be made vivid and real with the type of approach used by

Gordon Childe in *Man Makes Himself** and *What Happened in History*.† This method links the study of history and geography with that of other sciences, and although it requires more care in combining the different subjects in the curriculum a more unified world picture results. Some knowledge of the history of science and technology will enable a pupil to form a coherent picture of the life of ordinary people at different stages in human development, and to realise the possibilities for future progress.

Thirdly, it is essential to teach the scientific and technical basis of everyday life, concerning, for example, the avoidance of disease, nutrition and the principles of diet, human biology and sex, the general background of modern technology (electric power and lighting, aviation, cinema, radio, etc.). The details to be taught should depend on the stage of education reached. With the aid of films, charts, etc., it should be possible to cover the general background required, without devoting a disproportionate amount of time to it.

It is now necessary to consider how, within this framework, science should be introduced at the various stages of education. Emphasis should be laid on the gradual learning of scientific method by experimentation, and by deducing scientific generalisations from simple everyday facts and observations, rather than by starting from the validity of chemical formulae and physical laws. Science should be presented as an ever-growing body of knowledge, not as an accumulation of facts to be memorised. The scientific knowledge gained should be related to everyday experience and to the stage of knowledge gained at the same time in related subjects. In attempting to relate science teaching to the everyday life of the child it would clearly be of advantage for the teacher to be in close touch with out-of-school activities, as is suggested in the McNair report, and to gain the co-operation of the parents through active parents' associations.

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* Published by Watts & Co., London, 1936.

Published by Penguin Books, 1942.

From Infancy to Eleven Years of Age. A considerable amount of research has already been carried out on methods of teaching the very young. Emphasis is generally laid on acquiring simple health habits, and on encouraging natural curiosity and creative ability by simple practical work, generally in groups. At a later stage natural history can be taught through field expeditions and picnics. The children can examine the structure of outstanding natural features of the locality and learn to recognise the local animals and plants. The importance of the early technical discoveries, such as fire and use of metals, can be illustrated by stories and plays. In some schools the children will be able to take part in tending a school garden and looking after rabbits or hens, in conjunction with the study of elementary biology. Practical work in domestic science could be accompanied by simple explanations of some of the procedures.

The Secondary Stage of Education: Eleven to Sixteen Years. At this stage (considered as the period up to School Certificate or equivalent examinations) it appears more desirable that science should be taught as "General Science" to all pupils, than that one or two subjects (e.g. physics or chemistry) should be taught on the "science side" and no science at all on the "arts side." General science should include elementary physics, chemistry and the biological sciences, with opportunities for practical work, frequent field excursions and the collection of data. The teaching of mathematics and elementary statistics should be closely linked with the science teaching and should have a very practical approach. This type of teaching should eliminate the idea that mathematics is an inherently difficult subject which can only be understood by the exceptional pupil.*

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* See *Mathematician's Delight*, by W. W. Sawyer, Penguin Books, 1943.

As far as possible the syllabus should be related to problems met in everyday life. If practical work is treated as a means of studying the principles underlying the functioning of the machines and organisms commonly met, it will prove of more interest and have more a lasting effect than if treated as a means of illustrating theory. For example, during field excursions material can be collected for aquaria, the maintenance and observation of which will teach much about the conditions of aquatic life. Experiments in plant nutrition and manuring can be carried out in the school garden, the records being kept by the pupils. In any experiments on school diets the pupils could be told about the experiment and could assist in keeping records. Visits to local clinics and hospitals and talks from the local Medical Officer of Health would teach them about health services and make them active advocates in such measures as the diphtheria immunisation campaign. Weather logs could be kept, with the children taking turns at rain, temperature and wind measurement. Physics should include the mode of action of the electric bell, telephone, camera, telescope, pumps, refrigerators and, in a preliminary way, radio. Sometimes not all the benefit would go to the children; an enthusiastic teacher could arrange experiments so that information of real scientific value would be obtained. In some country schools the teachers have co-operated with research scientists in carrying out crop experiments, and it would please the children to know that they were helping in "real research."

At this educational stage it is important that attention be paid to education in hygiene and sex. Sex education has always been a problem which schools have tended to shirk. It is better to approach it through the biological study of the functioning of the human body than to look on it as a purely moral problem to be dealt with at a later stage.

The general scope of science teaching should be the same at all the three types of schools proposed under the new

Education Act, although in the technical schools more emphasis will be laid on the technical aspects of the subject. It should be possible during this period to cover enough of the broad principles of science to give the future citizen a basis for a rational appreciation of the world. It does not appear desirable that at this stage there should be a separate science course for future scientists. The general science course should be an adequate basis for future specialisation.

Education after Sixteen. Specialisation in many schools has already begun at the age of twelve or thirteen and becomes intense in the sixth forms, after matriculation. This is a result of the scholarship examinations of the universities and the need for a pupil to get high marks in the Higher School Examinations if he is to obtain State and County Scholarships, whether it be for the prestige of the school or for his own economic advantage. Specialisation has reached such a degree that a pupil may pass successfully through the school and obtain a university scholarship in the physical sciences without any knowledge of biology, or vice versa, and receive no formal instruction in literature or languages after matriculation. The whole basis of the Higher School Examination should be changed so as to conform with a more balanced educational curriculum. All pupils should learn some social science, concerning local and national government and the affairs of society; this should be introduced into the curriculum at an earlier stage.

It may be suggested that the requirements for the arts higher certificate should include also a subsidiary science subject which could cover such fields as heredity and genetics, nutrition, health and disease, geology, ecology of plant and animal communities. It would probably be preferable to have one general science subject, with considerable latitude for individual preference in studying certain fields more thoroughly, although it might be argued that a more rigorous study of a single subject, e.g. geology or zoology, would be a more useful discipline. In either case a minimum amount of practical work should be compulsory. For the scientists a minimum standard should be required in physics, chemistry, mathematics and biology. General biology should replace the separate "subjects" of botany and zoology which have the unfortunate tendency of separating animate nature into two sections which are often never related again. Additional subsidiary requirements should be: the social history of science (a subject much more interesting than the succession of biographies of famous men which too often forms a history of science course); English language and literature; a foreign language (Russian is likely to be the important second language for scientists in the near future). These proposals would certainly entail a lower standard in the subjects usually taken in higher school certificate and university entrance examinations. This would be no bad result, since the brilliant scholars find that their first year or more at the university covers no more than they already know and waste that time which could have been otherwise well spent. Those pupils not proceeding to a university would receive a much broader education and would not be forced in subjects which they will soon forget.

County Colleges. The general introduction of continued day-time education up to eighteen years of age as laid down in the Education Act will provide great opportunities and some problems. There is general agreement that education in these County Colleges should aim primarily at developing the individual and the citizen. Adequate facilities for vocational training should also be provided in addition to the time to be spent in the colleges, which in any case start inadequately with one day per week. It should also be remembered that the young men and women at these colleges will have just entered upon a new, wider and freer life and their teaching will require to be approached very differently from that of school-children. Any academic or isolated approach to subjects would be certain to fail; even cultural subjects, if unrelated to the life and problems of the students, would lack interest. Starting from the work of the young people, the economic structure of the area and the place of individual firms and jobs in it should be studied, together with the role of Trade Unions, employers' associations and other societies. The dependence of industries upon scientific progress can be illustrated. Further, the social role of science in the health services, nutrition, and factory welfare should be taught so that the young employee becomes aware of the importance of these facilities. From this beginning, wider horizons of municipal, national and international organisations can be reached. It is important that physical education should not be neglected, if the standard of general health and physique of the community is to be improved. The principles of health and nutrition should be taught and interest should be fostered in hobbies and leisure activities.

Staffing and Buildings. Most of the educational proposals being made at the present time, including those made in this book, would require more teachers and smaller classes than at present if they are to be carried out effectively; this is particularly true of laboratory and field work. The methods of training teachers should be studied and improved. The science teacher should be encouraged and enabled to maintain contact with research scientists and with local scientific societies and institutions, and should be enabled to attend refresher courses and vacation expeditions. During the next few years the shortage of teachers and buildings will be acute. Measures should be taken immediately to assure a sufficiency of teachers, and a very high priority should be given to the repair of schools and to the building of new ones.

Research on Educational Methods. Education is a major enterprise of our society. Under the new Education Act (1944) everyone will be directly affected by it for at least the first quarter of his lifetime and the national and local expenditure on education will be of the order of £200,000,000. Yet this important section of our social system has been allowed to develop without any adequate organised research into the methods used. In *The Study of Education in England* (London, 1943) Sir Fred Clarke said that if we conducted our medical and engineering services and industrial production in the same way as we carry on discussions about education "most patients would die; most bridges would fall down and most manufacturing concerns would go bankrupt."

Recently there have been signs that the need for more research in education is being recognised. In 1942 a Foundation for Educational Research was established and this prepared the way for a National Foundation for Educational Research in England and Wales which was set up in 1945 with the support of the Ministry of Education. The envisaged income of the National Foundation for 1947, however, is only of the order of £13,000. This minute sum, compared with the total expenditure on education, shows the scale of development that is still necessary before an adequate research effort can be achieved in this field. Under the new Education Act the Ministry of Education and the local Education Authorities have been given powers to conduct and to aid research, both by individuals and organisations. It is to be hoped that the National Foundation will act energetically both in formulating the major lines of research where immediate work is required, and encouraging teachers to do research work in these fields.

By the provision of incentives and of opportunities to do research it will be possible to utilise the immense fund of practical knowledge possessed by teachers and rapidly to develop the level of educational research in this country.

18

THE TRAINING OF SCIENTISTS

General. The main sources of graduates trained in science are the universities, while a not inconsiderable number come from the technical colleges (especially in engineering), and a very few through apprenticeship in the old sense. Before 1939 the number of graduates in science, including technology, from all the universities of Britain was approximately 3,700 per year, of whom rather less than a quarter became teachers in schools. There has been some increase in the total of science graduates during the war because of the institution of state bursaries and engineering cadetships, but the size of the post-war problem demands a tremendous increase in the number of scientists coming from the universities. This has been clearly recognised, both in the Report of the Committee on Scientific Manpower,* set up by the Lord President of the Council in 1945, and also in the Report of the Committee under the chairmanship of Lord Eustace Percy on Higher Technological Education.† This will involve corresponding increases in accommodation and teaching-staff, quite apart from the need to modernise existing departments and to increase the size of the teaching staffs so that research may also be fostered. Before discussing these problems it is important to consider the kind of training that should be provided in the science courses, and how far the existing provisions need to be modified in order to give both a balanced outlook and the required degree of specialisation. In the immediate post-war period there will be acute problems in the retraining of students whose careers have been interrupted by the war, which may be considered in relation to the more long-term proposals to be made.

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* *Scientific Manpower* Report May 1946 (Cmd. 6824, H.M.S.O.). Report of a Committee appointed by the Lord President of the Council.

† *Higher Technological Education*, Report of a Special Committee appointed in April 1944 (H.M.S.O., 1945).

There appears to be little doubt that university science courses in the pre-war years were inadequate both in general arrangement (curriculum) and in the details of the syllabuses. Apart from ideal considerations, their deficiencies from the severely practical view-point of industrial and governmental needs have been rudely revealed by the test of war. Some of the resulting innovations which it was found necessary to introduce have been especially helpful in improving teaching methods and point the way for a full revision of courses.

Teaching Methods. The teaching of science has suffered considerably from the circumstance of its development under the influence of classical studies, with their essentially different outlook. The idea of a direct and continuous investigation of Nature as being of the very essence of science and the first duty of every aspiring scientist, and the feeling of the steady progress of our knowledge, seldom enter into the teaching in the universities. The application of scientific method to the technique of teaching science now appears to be essential; at present little of this has been done in British universities. It appears to have been assumed that a man good enough to be on the staff of a university is intelligent enough to be able to teach well without special instruction. In fact, he will start teaching largely on the same lines as he himself was taught by his professor and other teachers. The standard of teaching in British schools has improved considerably in the past twenty years, whilst that in the universities has changed little. The Science Masters' Association has done very good pioneering work on science teaching in secondary schools. In the U.S.A. much thought has been given to this problem, and much can be learnt there both as to method and the writing of text-books. The war prompted a model experiment in the organisation of the admirable Conferences of Radio Teachers in Universities. These conferences were concerned as much with basic methods as with the handling of entirely new parts of the Physics course. Not least were they valuable for enabling the exchange of views between "producers" and "users" of scientists, between the university teachers and the research directors from the Services and industry. It was possible to compare the knowledge and qualities imparted by a university training with those that practice showed to be most desirable in a radio-scientist in war conditions. Such conferences should be held regularly for all branches of science, possibly with the assistance of Departments of Education. Special care needs to be exercised by professors and senior lecturers in directing the attention of assistant lecturers and demonstrators to the problems involved in teaching. These might well form the subject of occasional discussion in the colloquia on current problems of research which are already held in most departments.

The development of the lecture-demonstration and of the "examples class," where students are able to get assistance in handling the basic numerical methods of their subject, merit consideration. War-time experience of a modified tutorial system, with groups of four to eight students, and the experiment of "quizzes" made in some laboratories, also need discussion. But above all the science course should be designed so that the *method of science* is made clear to the student and that he may gain confidence in his own ability to use it. As many students as possible should undertake some minor piece of research in the final year; this is already obligatory for Honours degrees in some science departments. But consideration should be given to the practicability of introducing "research" problems at a much earlier stage in the university course, if only in the form of a complex "stock" experiment requiring several days for execution. The innovation of team-work on experiments, introduced inwar-time radio instruction, may be worth retention and elaboration. In every way students should be encouraged to ask questions and to try to find the answers by individual inquiry and group work.

Along such lines, with regular discussion in conferences and in scientific journals, university science should now be able to develop methods that will inculcate the essentials of the scientific outlook in its graduates. They will then be equipped to meet the new environment when they come in contact with the complex problems of industrial science or of teaching a lively-minded sixth form. Once the right attitude of mind has been developed, it will not be difficult to persuade graduates of the value of periodical refresher courses, in which they can contribute something from their own specialised knowledge, whilst getting an up-to-date revision of their subject.

Curriculum Reform. One of the problems in reforming university courses is to decide at what stage specialisation should begin. In pre-war years specialisation was excessive both from the point of view of science and from that of the individual scientist. The problem is common to all university faculties, being partly due to the economic pressure of competition for posts, especially among Honours graduates. But the problem is urgent in university science teaching, because there is a strong trend towards breaking down the barriers between the separate subjects (as usually taught) both in fundamental research and in applied science. Although much fundamental work will continue to be done in physics and chemistry, their further development is especially needed in biological fields. Similarly the progress of industries based on applied physics and chemistry has been great and will continue, but it seems probable that the greatest relative advances in the near future will be made in agricultural and medical fields. Thus the future calls, both in teaching and research, for graduates well trained in scientific method, with a broad general knowledge of science and its applications, and able to work in border-line fields of science. The narrow specialist will be much less useful here. The problem of early specialisation in preparation for entrance to the universities should be overcome if the proposals of the Norwood and other reports for broadening school curricula be implemented.

The Association of University Teachers and other organisations have proposed that specialised study should be postponed until the third or fourth year of the degree course. The first two years should include general studies in at least three subjects, not necessarily all scientific, plus the requisite subsidiary mathematics. At the end of this time a choice should be given of proceeding either to a Special or to a General Honours degree. The Special Honours degree would involve two years of special study, ending with a piece of research work, which should be obligatory for those intending to go into research and optional for teachers. This piece of research work would not only be an excellent testing-ground and apprenticeship in research, but would also provide the most effective means of appreciating scientific method. The General Honours degree would entail, after the initial two years, a further two years of general study with optional specialisation to a minor degree, special subjects being freely available. This General Honours degree would be taken chiefly by intending teachers, for whom group-work in a social or geographical survey of the locality might be the best introduction to research methods. In all courses it would be essential to provide, in all, four years of study in order to graduate, as soon as accommodation and staff allow. In science more than in any other subject except medicine, such a period is needed for adequate introduction to the existing state of knowledge. In view of the urgent need for teachers it may be necessary to keep the General Honours course to three years at present, with an additional year of professional training. Interim measures should include experimentation with special science lectures (especially in biology) for teachers, who would not normally attend the specialised lectures provided in the final year for intending research scientists.

As part of this broadening of curriculum, lectures and seminars should be organised in the history and method of science, which are better studied systematically at this stage rather than at school. Such courses should not be narrow catalogues of brilliant men and major discoveries; they should convey an integrated survey of the progress of science. The history of ideas, the evidence of archæology and anthropology, modern views of the evolution of the individual and of society, and the social implications of science should be included. It is to be hoped that more chairs and lectureships in the history and method of science will be established. The type of course outlined would require the collaboration of a staff of specialists in different branches of science. It would be a most effective means of broadening the outlook of scientists and of bringing the cultural and historical importance of science before those engaged in other studies. Already one university provides a course on the History of Man for all first year students.

Syllabus Reform. The content of science courses stands in urgent need of review. It was realised even before the war that radical revision was overdue, in order to bring the courses abreast of modern advances. The needs of war have forced the process of revision very rapidly in technically important branches such as radio. What now appears to be required is adequate machinery for the easy and periodical revision of syllabuses in normal times. In Arts subjects the need for revision arises only over long periods, and there is ample time for even the most hidebound to get used to new ideas. In science, a period of ten years can produce radical changes in fundamental outlook as well as in detailed knowledge. Before the war in many places the syllabus for science subjects was much more than ten years out of date.

The neglect of applied science in the universities should be remedied. In the universities the sciences have tended to be regarded as set bodies of knowledge without recognition of their essentially practical character. That their origin and importance lay essentially in man's struggle to survive and in his efforts to conquer his environment, was overlooked, or, at least, not explicitly recognised. The theoretical division between so-called "pure" science and applied science has often been fostered in university circles and some individuals have preached the independence and complete autonomy of "pure" science. While the distinction between fundamental research and applied or development research can be recognised, the distinction between "pure" and applied scientific knowledge is untenable. Degree courses should pay more attention to the practical ends of science, making clear that the application of science is one with and indivisible from the extension of man's knowledge of the universe in which he lives.

University science courses should be modernised in three main respects, the relative urgency varying from subject to subject. Firstly, the latest important advances in factual knowledge and practical application need to be included. Secondly, a survey of the needs of the student should be made at intervals, so that courses on related topics of theoretical or technical interest may be added. For instance, many branches of science now make increasing use of statistical methods; the stage at which students should receive the necessary special instruction in statistics should be carefully considered. Thirdly, the whole basis of presentation of a subject requires to be reviewed at irregular intervals, dependent on advances in fundamental interpretation. In physics the time is now ripe for such a thorough re-orientation. This would involve the writing of new text-books from the view-point of modern theory, and the reorganisation of practical courses.

These major changes can only be initiated through strong representative bodies of scientists themselves, such as the recently established advisory bodies on the teaching of physics and chemistry. This work should be extended to other subjects. An essential part of any revision would be the removal of much unnecessary detail in order to concentrate attention on main principles and inter-relationships. The initiative of the Cambridge Higher School Examinations Board in producing new syllabuses points the way, at one level, to what would appear to be the correct type of solution.

Continuous liaison with past graduates is important for keeping university departments in touch with changes in the applications of science and in the relative importance of subsidiary subjects for the research worker (e.g. in different branches of mathematics). The interchange of experience, as well as of personnel, is most important in order to maintain effective links between academic and industrial science, and thereby to keep syllabuses up to date (see Chapter 15).

The needs of war developed schemes of vacation work industry in some sciences. Measures first taken by professional bodies to facilitate the attendance of students at State and industrial laboratories during the summer vacation have now been extended officially to include all State Bursars in the physical sciences. Experience of industrial methods of research, development and production, is an invaluable aid both to understanding much of the academic course and to acclimatising students to the type of post they will ultimately occupy (or of revealing their unsuitability). It would be valuable in peace-time if intending teachers also were to see something of science in industry, and extension of the scheme to other sciences should be encouraged. Practical industrial work during vacations should be possible and required in every branch of science. This appears to offer a more profitable use of the long vacation than proposals to retain permanently the Fourth Term, introduced to meet the situation created by shortened war-time courses. Some of the practical vacation work might be centred in university laboratories, with opportunities for students to go during the summer vacation to other centres to learn special techniques not taught in their own departments.

Number of Science Students. It is now generally agreed that the increase in the number of scientists required will be very great if the plans for economic expansion, already discussed, are to be carried out. In their report the Committee on Scientific Manpower stated the position as follows. The country had at its disposal in 1946 approximately 55,000 qualified scientists.* The estimated minimum demands for scientific workers in this country and in the colonial services in 1950 will be 70,000, of whom 30,000 will be teachers in the Universities and Secondary Schools. By 1955 the minimum requirements will be 90,000. The Committee considers that these figures probably represent an under-estimate (perhaps a serious under-estimate) of the number of scientists that will be needed, but even these figures demand that our immediate aim shall be "to double the present output, giving us roughly 5,000 newly-qualified scientists per annum at the earliest possible moment." Before the war, the output in Great Britain was approximately 2,500 qualified scientists per year in the scientific fields considered.

The report states that this need for a large increase will be a permanent one within our country. It is explicitly stated that "We do not think the Universities need be deterred from expanding their facilities . . . by any fear that this will leave them with excessive staffs and accommodation once the demand for qualified scientists has levelled out." In fact, it is believed the demand is likely to continue to expand for an indefinite period. The report states:

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* *Scientific Manpower* Report (H.M.S.O., 1946). In the Report, qualified scientists are defined as "persons holding degrees in the mathematical, physical, chemical and biological sciences, together with the small number of men and women who, without being university graduates, are members of recognised scientific institutions with a membership status that is accepted as the equivalent of a university degree in these subjects."

> "If the active life of the average scientist should prove to be in the neighbourhood of thirty years, an output of 5,000 science graduates per annum postulates an ultimate total force of 150,000 or over one and a half times the force we consider will be required in 1955. The Universities may therefore have misgivings about attempting to provide accommodation and teaching staff sufficient to cater for 5,000 science graduates per annum. We think, however, that the dilemma is more apparent than real. In the first place although the demand for scientists may not reach 150,000 for many years to come, there is reason to expect that for an indefinite period it will continue to expand for, apart from the increasing application of the physical and chemical sciences not only to research, but also to production in industry, there is a wide and expanding field for the application of the biological sciences.
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> "Secondly, by 1955, a large proportion of the accommodation at present used by Universities will be fit only for demolition and need not be rebuilt if the demand for it has ceased to exist.
>
> "Finally, we hope and believe that scientific training will come to be in greater demand as a foundation of a general education. Hence we do not believe that, even if the demand for recruits to the scientific professions should at some future date fall below the supply, it is likely that a reduction in the student body in science faculties would take place."

There will be general agreement with the demands of the Committee for an immediate large increase in the number of scientists to be trained. Criticism must be directed rather to asking if the Committee has not been overcautious in its approach and has based its figures for expansion more on what the universities can reasonably easily achieve than on what will be the real needs of the country. There is a considerable body of opinion that the country needs at least to *double the number* of working scientists (which is a much bigger task than to double the *output*) not in the remote future as the Committee suggests, but within the next ten or fifteen years; and it is clear an even larger proportional expansion in the number of science teachers will be required. The speed of our development will have its effect in the immediate years ahead which will be crucial for Britain's economy, and it is vitally important to face the immensity of our task if we are to catch up and maintain our scientific effort on a level comparable with the U.S.A. and the U.S.S.R. Such required increases present the universities, not only with big problems of accommodation for students, but also with the need for a large increase in staff. In fact, there must be a more than proportionate increase in staff because of the necessity to lower the ratio of students per member of the staff, in order to make the teaching more efficient and to provide more time for university teachers to engage in research work.

It may well be asked how the universities can meet this situation and whether sufficient man-power of the right quality will be available.

Expansion of Training Facilities. In view of the importance of science to the future of the community a high priority should be given, in allocating building and equipment licences, for meeting the needs for training science students. Temporary arrangements need to be made, in most places, to deal with the inrush of students; this is certain to outpace new building. Certain Government Research Stations and perhaps military camps and hospitals could be used for special courses, using munitions hostels for housing the students. Some universities are erecting temporary buildings of light factory type which serve admirably for laboratories, lecture rooms, or even hostels. These are, however, only emergency measures; plans should be formulated immediately for permanent large-scale expansion to meet the increased numbers of scientists and teachers. It is doubtful whether existing universities can grow as rapidly as is needed, and the possibility of forming new universities requires consideration. If, meanwhile, some of the University Colleges reach the requisite size and standards, they should be given university status. Similarly, Government Grants should be given to certain Municipal Colleges if they sufficiently increase their full-time courses.

The question remains as to whether these large numbers of intending scientists and teachers will be forthcoming from the schools, and whether a sufficient proportion will be of the quality required for expanding the academic staffs. The experiences of the war, including the results of providing State Bursaries and Engineering Cadetships, have confirmed that the nation has large reserves of intelligence to be tapped by the proposed reorganisation of secondary education. A great increase in the number of applicants for entrance to the universities in five or seven years' time may be foreseen as the result of it. This increase will be all the greater from broadening higher school studies and providing General Honours courses for degrees. Intelligence tests have shown that about one-third of the best elementary school pupils did not go to a secondary school in pre-war days. The Board of Education figures show that only 10 per cent of secondary school entrants got as far as taking the Higher School Certificate, and of these only half went on to a university. There is therefore no doubt that more than enough applicants of high intelligence will be available to fill the projected five-fold increase in the number of science students at the universities. But this will be possible only if adequate maintenance grants be provided to allow all children showing aptitude to remain at school until eighteen and to proceed to the universities. The Committee on Scientific Manpower amply confirm this position. On this subject they conclude:

> "There is available in the population a large reserve of innate intelligence. Its size is such that, while recognising the need for other qualities also, we assume that there is available more suitable material than we could hope to take into our Universities by any degree of expansion practicable within the next ten years. But financial assistance must be forthcoming on a larger scale if much of the available talent is not to be lost to the Universities."

The shortage of staff in the universities presents a different problem. It will be necessary to increase the staffs at least as rapidly as students increase in numbers, and also to make up for the lack of normal replacement in the past five to six years. Within about five years the universities should be meeting their own requirements by retaining the best graduates each year, but the immediate needs for expansion will be so great that an emergency scheme should be planned now by the university authorities. It cannot even be assumed that all former members of staffs will wish to return to academic life from their war-time occupations. The adequate staffing of the universities by people with the right qualifications for teaching and research is a key problem. The plans should include the assurance that the expansion will be big enough to ensure time for research on the part of all teachers, and that salaries will be raised to a level more comparable with those in industry and the Government service. Within the universities steps should be taken at once to retain the most promising undergraduates as demonstrators. To attract recent graduates back to the universities in competition with openings in industry and in the State scientific services, Senior Research Studentships should be instituted on a large scale. The holders would be available to assist in teaching, but their main time should be devoted to advanced study and research. The Government Grant should make available the means to provide up to 500 such awards annually, ranging in value from £350 to £500 per annum.

Scientific workers engaged on research work in fields other than the universities should be given the opportunity, if they wish, to engage in part-time teaching in the universities. This scheme could be applied to scientists in Research Associations, industrial or State laboratories to enable them to teach locally. But the main burden will have to be borne by teachers of experience; every effort should be made to reassemble quickly those who have been dispersed on war-work. The maintenance of teaching standards can safely be left in their hands, provided that full provision be made for the expansion of staffs as qualified candidates become available.

Technical Colleges. The problems of higher technical education are very different from those of the universities and are even more urgent. In the past this part of the educational system has received the least attention and financial support. It has developed piecemeal, and there is great variation in the extent and standard of instruction in different parts of the country. The local provision varies from small technical colleges to colleges of the type developed at Glasgow and Manchester, which have full-time courses leading to a degree, diploma or Higher National Certificate. In 1938 the number of part-time students at technical colleges exceeded one and a quarter millions, and there were 43,000 full-time students—only 15 per cent fewer than at the universities. The demands of post-war industry are certain to require a large increase in these already large figures.

The Education Act of 1944 makes provision for development of technical education beyond the £12,000,000 programme started before the war, which was in itself a belated recognition of the size of the problem. The Percy Committee* in 1945 reported on the position of Higher Technological Education with special reference to the engineering industry. They stated that the evidence submitted substantiated the general view

> "first, that the position of Great Britain as a leading industrial nation is being endangered by a failure to secure the fullest possible application of science to industry; and second, that this failure is partly due to deficiencies in education. The annual intake into the industries of the country of men trained by Universities and Technical Colleges has been, and still is, insufficient both in quantity and quality. We believe that the industrial demand for such men will increase in quantity after the war; and that the demand for higher quality, especially in certain categories, will become more insistent as the nation becomes more conscious of its need for technical efficiency. In particular, the experience of war has shown that the greatest deficiency in British industry is the shortage of scientists and technologists who can also administer and organise, and can apply the results of research to development."

In the particular fields of engineering they believed that it was essential that the 50 per cent increase of engineering students during the war must be maintained for at least the next ten years. They also considered that it was necessary to organise in a certain number of Technical Colleges courses of a standard comparable with that of University degree courses, which would give particular attention to the "development to the highest level of the teaching of the art of technology based on a sufficient scientific foundation." The report further stated:

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* *Higher Technological Education;* Report of a Special Committee appointed in April, 1944 (H.M.S.O., 1945).

> "We recommend also a continuance, both for Universities and Technical Colleges, of the special State Bursary system, with improved methods of selection, and the extension of the benefits of this system to candidates from industry as well as from secondary schools. Indeed, we would represent strongly that the whole question of scholarships for students of technology needs thorough reconsideration. At present, the student entering full-time or semi-full-time education from industry, instead of up the normal ladder of full-time secondary education, tends to fall altogether outside the national scholarship system. Industry itself does something in this field, and might do more; but the State should do much more. Unless it does so, the whole idea of full-time or semi-full-time courses in Colleges of Technology must break down. We hope that the State, having discovered during the war that special bursaries and cadetships can attract a new supply of able students, will not neglect to apply that experience to the hardly less urgent problems of peace."

In part-time education it should be made obligatory on employers to release intending pupils to take courses in the day-time on a number of half-days in the week, in order to overcome the heavy strain of night-school work, which is largely responsible for the small proportion of these students who complete part-time courses.

The Education Act makes it a duty of local authorities to submit schemes for technical education to the Ministry of Education, and to consult with neighbouring authorities, the universities and other bodies on this subject. This recognition that technical education should be treated as a regional problem is to be welcomed. It has long been agreed, however, that further powers need to be provided in order to ensure properly co-ordinated regional development. The Minister of Education has now recognised this by setting up Regional Councils for Further Education to decide questions such as the relative size of institutions and their specialisations and concentration, and Regional Academic Boards to give detailed attention to syllabuses and courses. Through concentration, some institutions in one region could be devoted mainly to full-time courses, the institutions possibly rising eventually to the status of university colleges or colleges of advanced technology as advocated in the Percy Report. It would be improvident to attempt, as often in the past, to combine all stages of technical education in one building, from the junior-school level to university degree standard. There should be more institutions concerned with teaching higher technology, largely by full-time courses and in collaboration with the universities, and more departments of applied science in the universities. The latter should be chiefly concerned with the theoretical basis of practical processes, to produce people for research in a particular field, such as colour chemistry, technical optics and agricultural botany. On the other hand, the colleges of technology should be chiefly concerned with the practical details of applied science and in giving a more directly vocational training to students coming usually from the technical schools. The colleges of technology should aim to produce engineers of high qualification rather than applied scientists. Both types of institutions, applied science departments at the universities and colleges of technology, are required, and their growth and work should be co-ordinated.

The universities should help actively to develop higher technical education in their regions, the technical colleges being in close liaison with their nearest universities and sharing amenities with them. There will be a great need for co-operation where there is a shortage of teaching staff and equipment for special subjects. The universities have a great responsibility for closing the gap between academic and applied science.

Special attention should be given to the problems of technical teachers and adequate machinery should be provided for recruiting and training sufficient numbers of them. The majority of technical teachers will continue to come, and rightly, from among the industrial scientists who offer part-time help. But an increasing number of technical teachers should have full-time appointments, especially in view of the projected increase in full-time courses. Both classes of teacher will probably require some training in exposition; this has been lacking in the past. The necessary teachers will not be forthcoming unless salaries, general conditions of work and facilities for further study and research are much improved. The McNair Committee on the provision of teachers has recognised these problems and has called for the proper remedies in its report. It remains for local authorities to put them into effect and for the State to make available the requisite funds. It is astonishing that Britain, one of the most highly industrialised countries in the world, should have so greatly neglected that technical education on which its further advance so much depends. Immediate action in the interests of the whole community is necessary.

The Training of Laboratory Technicians. The provision of trained technical assistants, laboratory technicians for industrial laboratories is an increasingly important problem shared with the universities and other institutions. Organised arrangements for training, and great improvements in status and remuneration are overdue. Laboratories now have need of a great variety of highly-skilled technicians, e.g. instrument-makers, glass-blowers, analysts, research assistants in specialised fields (physiology, bacteriology, histology, photography, etc.). Laboratories are complex organisations in which essential services are provided by the work of store-keepers, laboratory stewards and the various specialist technicians already mentioned. The number of technical assistants has not increased at the rate required by the expansion and increasing complexity of research. Young people will only be attracted to this work when it is seen to afford prospects of a real career. Recognised schemes of organised training with suitable diplomas are needed to make it a recognised career with real prospects.

The establishment of courses of instruction in laboratory arts is one in which universities and technical colleges could collaborate. These courses should provide for continued general education (at least until the proposed County Colleges are available); without this the special technical instruction would be hard to impart. Classes in laboratory techniques, e.g. glass-blowing, are sometimes available at local technical colleges; where they are not, they could be instituted, jointly with the universities, in the most appropriate place, possibly in university laboratories as vacation courses. Specialised instruction will usually be obtained from the senior technicians in the department in which the assistant works. With the increasing need for degree students to have knowledge of workshop practice the universities might organise a special training department for students and technical assistants. One or more of these departments might eventually be built up into a source of highly specialised craftsmen, on the lines of the famous Leyden school for metal-work and glass-blowing.

It is necessary radically to improve the wages and working conditions of technical assistants. It is still possible for skilled men to be earning no more than £4 per week in research laboratories, and for a laboratory assistant of twenty-one to be paid at a lower rate than a charwoman in the same department; the situation is particularly bad in some university departments. Attention should also be given to the provision of better pension schemes, canteens and recreation rooms; in larger establishments there is place for the appointment of welfare officers, to be responsible for all such matters. Skilled technical assistants are now an indispensable part of the personnel of all laboratories; it is time that their training and working conditions were more closely related to their value to science.

19

THE POLITICS OF SCIENCE

The Social Problem. The Second World War has graven in the minds of most inhabitants of the globe a vivid awareness of the power of applied scientific knowledge. Atom bombs and the threat of "biological" warfare are now given much publicity, and it is easy to curse science and scientists. But the real lesson which the development of "scientific" weapons should make as clear as daylight is: when sufficiently large resources of finance, organisation and scientists are used there are few problems of the control and exploitation of Nature that cannot be solved, and often with unexpected speed.

The scientific effort of the United Nations was directed to the military defeat of Germany, Japan and their satellites as the most aggressive enemies of social progress throughout the world, and there is no need to emphasise what would have been the results to the life of ordinary men and women if Fascism had succeeded. That defeat was achieved; and from it have come great advances in scientific knowledge and application, exemplified in their most dramatic form by the atom bomb. But to balance this picture of science used for war purposes one has only to imagine what progress could be made in the defeat of social scourges such as cancer, tuberculosis and other diseases which take a continuous toll of human life greater than any war, if an equally great and co-ordinated scientific attack were made upon them. Similarly with the use of science to raise agricultural and industrial productivity as the material basis for abolishing hunger and want from the world.

Particularly among scientists, many of whom stood aloof from politics and parties, a new and more vivid awareness has arisen of the need for the social control and social use of science and of the dangers which threaten if it is not so controlled and used. The atom bomb epitomises the dilemma which to-day faces society: the applications of science can be for destructive or constructive ends. It is for men and women to choose, and that choice is made by individuals deciding what kinds of governments they empower and what policies they shall pursue.

The object of this book has been to point out the possibilities for technical advances in Britain, in the belief that the potential applications of science are, on a world scale, so great that world-wide freedom from want and disease could in fact be achieved within a hundred years. The benefits that science could bring have for long been in advance of the uses which society has made of them. The frustration of science, the failure to use existing knowledge, was a commonplace of the years between the wars, when human needs were perhaps greater than at any time in history. It is evident that the existence of needs is no guarantee that they will be met. Consequently every man and woman has to face the cardinal problem: How is science to be used in order to secure the full satisfaction of human needs?

Present Prospects. Three necessary conditions have been indicated in Chapter 1—international political and economic co-operation, the development of backward regions and domestic policies in all countries aimed at high and rising standards of life. These conditions have been embodied in numerous international declarations of the highest importance. The setting up of the United Nations Educational, Scientific and Cultural Organisation (UNESCO); the proposals for a World Food Board; the Bretton Woods agreement with proposals for an International Monetary Fund to stabilise international exchange and for an International Bank for Reconstruction and Development; all these have widespread potentialities if rightly used for improving the world's social standards. The task of all men and women is now to ensure that their Governments fully realise that international co-operation is the first essential to progress, and that there shall be absolute opposition to those who seek to precipitate dissensions between different countries, particularly between the Soviet Union and the United States. Within Britain itself the war has brought great developments in the political temper of the people which augur well for the future. The policies of restrictionism and political reaction which prevailed between the wars have been rejected; a determination to build a better social order is widespread. The first major step was taken with the election of a Labour Government broadly pledged to the type of policy we have seen to be necessary. The majority of British electors have refused to support negative and antiquated formulas which would in practice have led to a continuance of the old order of affairs.

Scientists and Government. The task of a government is to relate its social objectives to the material and factual possibilities, and the mobilisation of scientific advice and effort is a necessary condition of its work. Proposals for organisational steps to secure the full use of science have been outlined in Chapter 14. For such an organisation to fulfil its role, there must be working in it scientists who themselves understand the Government's social objects. Scientists, in order to give maximum service in the application of their knowledge, must have an understanding of social and political problems. It is encouraging, and a sign of the greater integration of science into social life, that more and more scientists are accepting this view, and many are realising how their scientific interests are bound up with progressive policies. Formerly, scientists in general stood aloof from politics, taking refuge from a stormy world in the seclusion of their own researches. But gradually many have realised that "no politics" often means "no progressive politics," leaving a free field for reactionary obscurantism. The changes of the modern world are rapidly destroying this attitude of aloofness to political and social questions. The younger scientific workers, especially, see no reason why they should not participate in politics, since politics so profoundly affect them.

At the same time there is not, fortunately, among scientists any widespread acceptance of the "technocratic" point of view, which sees the technicians as the real ruling class in society, benevolently dispensing benefits to ordinary men in accordance with their needs. This fantastic but internally logical development of the Platonic master and slave relation is entirely opposed to the purposes of this book. The ultimate responsibility for securing a progressive policy and the full use of science depends not on scientists but on every citizen. Scientists, as such, have no peculiar rights of leadership; they may be more informed than other men in special subjects, but not necessarily in general social matters.

Scientists have need to express their views independently as well as in advising the Government. The Association of Scientific Workers has attempted this task in Britain since 1918. In the last few years, particularly during the war, similar organisations have developed in a number of other countries, and the increasingly international aspect of post-war science problems has greatly increased the need for permanent liaison and co-operation. In July, 1946, in London, an international conference approved final plans for the inauguration of a World Federation of Scientific Workers to promote co-operative action between the various national organisations in order to achieve the fullest utilisation of science in promoting peace and the welfare of mankind.

Scientists and Citizens. If responsibility in these matters rests ultimately on the citizen—as in a democracy it must—then the citizen must be aware of and evaluate the technical as well as the social aspects of the problems. Democracy needs a greater technical awareness, a rise in the standards of social and technical thinking. The relation of scientist and citizen may be summed up by saying that the scientist should play his part more fully as a citizen, while the citizen should acquire more and more scientific awareness. The changes in the educational system suggested in Chapter 17 would help to bring these changes about. Scientists themselves have a positive part to play in this development and in the general educative process which it implies, through popular lectures, through articles in the Press and through other publications. Scientific organisations should play an active part within the framework of our adult education movement. Close links are needed with citizen organisations, e.g. the community centres, consumer organisations such as the Co-operative Societies and workers' organisations in the Trade Union movement.

In the carrying out of the Government's policy, the Trade Unions, as an important sector of support for a Labour Government, have a special responsibility. Their attitude towards scientific development in industry and the general use of science is therefore of great significance. During the war, the organised workers became increasingly aware of the contribution science can make to industrial efficiency; trade unionists, nationally and locally, have come into closer association, on control boards and on Joint Production Committees, with the running of industry. They have in consequence a new realisation of the importance of technical questions, and of the power of science and technique to serve socially progressive ends. So long as a policy of economic expansion providing full employment is pursued, advances in production methods giving increased efficiency and output would be supported by the Trade Unions. Several unions, in preparing to meet the problems of peace, have used the help of scientists and their trade union organisations. In many towns and cities scientific and manual workers have collaborated in considering the future of the industries of their areas. The Trade Unions are learning in this way to use, in the preparation of constructive and technically sound policies, the help of technical advisers who are themselves in sympathy with their objects; twenty years ago such advisers would have been hard to find. But since that time there have been great changes of outlook in the scientific profession. Scientific workers have been drawn more and more into industry and have become increasingly interested in the framework of industry within which they have to apply their results; and the common desire of scientist and worker for maximum and efficient production provided it does not cause unemployment, gives basis for mutual help. This is illustrated, for example, within the T.U.C. itself where in 1939 there was established a Scientific Advisory Committee. This achieved little because of the insufficient integration of scientists and scientific thought with the Trade Union movement. In 1945, however, it was agreed at the Annual Trades Union Congress, on a resolution proposed by the Association of Scientific Workers and supported by the National Union of Mineworkers, that the Scientific Advisory Committee should be reconstituted; this time there is much more hope of success.

The Government and the Citizen. The Government, too, has a part to play in the education of the public. The news of the first atomic bombs was followed by a considerable volume of official and semi-official publicity on the nature and importance of the invention. In the same way the technical information concerning social problems should be made freely available as they arise, so that public opinion may be informed and responsible. A widespread understanding of technical questions was one of the great sources of success of the Five Year Plans of the Soviet Union: it helped to release a flood of popular enthusiasm and inventiveness which overcame all obstacles and created in a few short years the industrial and social basis for the destruction of the greater part of the armed strength of German Fascism.

The Future Goal. This greater technical awareness may well have profound effects on the future development of society. Scientific advance is one of the most important causes of change in society, as technical advances change the relationships between men. The further developments of technique to-day affect the whole world and are fostering further changes in social organisation. The productivity of industry between the wars was too great for the products to be consumed by those nations whose social and economic organisation led to the continuous existence of poverty; hence economic depressions, struggles for markets, war. Modifications of national and international economic organisation aimed at achieving social advance are the methods with which the attempt can be made to meet the challenge of mounting productivity resulting from technical advances. As this comes to be more clearly and precisely understood, so the necessary social and political changes will come about more easily and smoothly; social development itself will be helped by the broadening of technical understanding among the people.

The recently ended war carried forward the world-wide social revolution of this epoch, "the century of the common man," to a new stage. Science offers means to use unprecedented powers with which a finer, more beautiful and happier world than ever before can be built. With mankind using a vigorously developing science for social ends, the future can be bright and inspiring.

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Number 2

Edited by John Enogat and R. E. Peierls

This second issue of *Science News* is devoted entirely to the subject of Atomic Energy, which is indeed science news in its most spectacular form. All the articles have been written by scientists who at the time when the plans for it were made were working at Los Alamos, U.S.A., on the project which eventually led to the first atomic bomb. Some are British, some American.

The first article contains a general survey of the whole field, and forms the key to the rest. The second and last articles explain the general background. The remainder deal with special aspects of the field.

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THE PHYSICS OF THE BOMB *P. Morrison*

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W. R. JONES, D.Sc., Professor of Mining Technology at the Imperial College of Science and Technology

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WHY SMASH ATOMS?

by A. K. Solomon

What we to-day call atom-smashing, the scientists of the Middle Ages called transmutation, a change in the kernel of the atom so violent that its elementary nature is altered. In the Middle Ages the problem was the conversion of metals into gold, the creation of riches from poverty.

Unfortunately, the forces required are so great that the alchemists could not possibly have been successful. It was not until 1919 that a scientist, Lord Rutherford, at Cambridge University, for the first time actually broke through the impenetrable barrier around the atomic kernel and succeeded in making one element from another, in altering the basic nature of one atom so completely that it became a different atom.

Rutherford's discovery opened the way to a significant increase in our knowledge of the fundamental constitution of matter. All over the world scientists are to-day engaged in atom-smashing. The results are not only transforming the sciences of physics and chemistry and producing an immediate practical effect in the field of medicine, but have been responsible for bringing to a conclusion the greatest war that has ever been waged in the world's history. For the atomic bomb was a direct outcome of this research.

Dr. Solomon, who has taken an active part in the work of one type of atom-smasher, the cyclotron, at Cambridge and Harvard Universities, has here explained for the layman the nature, purpose, and results of these epoch-making advances. This is popular science in the best sense of the term: a volume that reveals to the non-scientific reader the great sweep of modern research.

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THE ANATOMY OF PEACE

by Emery Reves

In a book destined to startle by the very nature of its simply stated truths, Emery Reves analyses the cause of war and the nature of peace. He finds that the only condition in human society that creates war is the unregulated relationship between sovereign social groups: that wars occur wherever and whenever sovereign power units come into contact.

Peace will exist, he declares, only when absolute national sovereignty, which causes anarchy in international relations, gives way to universal legal order—when the relationship between nations is regulated not by treaties but by law.

Since its first publication in June, 1945, over 150,000 copies of this book have been sold in America. It has been argued about by over 20,000 discussion groups in the United States. An open letter to the American people, urging them to read and study the book, appeared over the signatures of Owen Roberts, Associate Justice of the Supreme Court, Dr. Einstein, Thomas Mann, Christopher Morley, and a number of senators, clergy, and other public men in America.

Penguin Books have arranged for the publication of the book in Great Britain at a price which will enable every man and woman of good will to obtain and read it, so that the urgency of the problem of world reconstruction and this reasoned attempt to face the foremost issues of our time may be discussed as widely as possible.

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